A Programming System for Children that is Designed for Usability (Appendices)

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APPENDIX A

Language Syntax Chart

The HANDS language is defined by this JavaCC/JJTree grammar.

```
/**********************************************************/
/* GENERAL PURPOSE TOKENS USED IN MORE THAN ONE PRODUCTION */
TOKEN :
{
  < END:         "end"           >
| < LPAREN:      "("             >
| < RPAREN:      ")"             >
| < IN:          "in"            >
| < OF:          "of"            >
| < TO:          "to"            >
| < FROM:        "from"          >
| < INTO:        "into"          >
| < EACH:        "each"          >
| < COMMA:       ","             >
| < NOT:         "not"           >
}

/**********************************************************/
/* THROW-AWAY TOKENS: CAN APPEAR ANYWHERE AND ARE IGNORED*/
SPECIAL_TOKEN :
{
  < THE:         "the"           >
| < IS:          "is"            >
}
```

```
/***********************************************************/
/* Event */

TOKEN :
{
  < PROGRAM:    "program"       >
| < STARTS:     "starts"        >
| < STOPS:      "stops"         >
| < RUNNING:    "running"       >
| < APPEARS:    "appears"       >
| < DISAPPEARS: "disappears"    >
| < CHANGES:    "changes"       >
| < COLLIDES:   "collides"      >
| < CLICKED :   "clicked"       >
| < TYPED :     "typed"         >
| < ANYTHING :  "anything" | "something"    >
| < NOTHING :   "nothing"       >
| < HAPPENS :   "happens"       >
| < ANY :        "any"          >
| < KEY :        "key"          >
}

void Event() : {}
{
    <PROGRAM>       ( <STARTS>
                    | <STOPS>
                    )                   [ <RUNNING> ]

|   LOOKAHEAD(2)
        (   ( StringOrIdentifier()  <TYPED> )
        |   ( <ANY> <KEY> <TYPED> )
        )

|   [ <ANY> ] <IDENTIFIER>  ( <APPEARS>
                            | <DISAPPEARS>
                            | <CHANGES>
                            | ( <COLLIDES> [ <INTO> [ <ANY> ]
<IDENTIFIER> ] )
                            | <CLICKED>)

|   ( <ANYTHING> | <NOTHING> ) <HAPPENS>

}
```

```
/************************************************************/
/* When */
TOKEN :
{
  < WHEN:       "when"          >
}

SimpleNode When() : {}
{
    <WHEN> Event() (Action())* <END> <WHEN>
        { return jjtThis; }
}

/************************************************************/
/* Action */
SimpleNode Action() : {}
{
    (   If()
    |   With()
    |   Set()
    |   Math()
    |   ListStatement()
    |   TellUser()
    |   Make()
    |   Beep()
    |   PickUp()
    |   PutDown()
    |   Flip()
    )
        { return jjtThis; }
}
```

```
/***********************************************************/
/* CardField */
TOKEN :
{
  < POSSESSIVE: "'s"            >
}

void CardField() : {}
{
    LOOKAHEAD (Field() <OF>)
        Field() <OF> Expression()
|   Value() <POSSESSIVE> Field()
}

/***********************************************************/
/* Card */
TOKEN :
{
  < CARD:       "card"          >
}

void Card() : {}
{
    <IDENTIFIER>
|   CardFactory()
|   <LPAREN> CardField() <RPAREN>
}

/***********************************************************/
/* Field */
void Field() : {}
{
    <IDENTIFIER>
}


/***********************************************************/
/* CardFactory */
TOKEN :
{
  < NEW:        "new"           >
| < DUPLICATE:  "duplicate"         >
}

void CardFactory() : {}
{
    <NEW> <CARD> [ LOOKAHEAD (Expression() ) Expression() ]
|   <DUPLICATE> [ <OF> ] Expression()
}
```

```
/************************************************************/
/* If */

TOKEN :
{
  < IF:         "if"            >
| < THEN:       "then"          >
| < OTHERWISE:  "otherwise"     >
| < ELIPSIS:    "..."   >
}

void If() : {}
{
    <IF> ConditionAction() [ OtherwiseAction() ] <END> <IF>
}


/* ConditionAction */

void ConditionAction() : {}
{
LOOKAHEAD(HalfBooleanExp() <ELIPSIS> )
    SplitConditionAction()
|   WholeConditionAction()
}


/* SplitConditionAction */

void SplitConditionAction() : {}
{
    HalfBooleanExp() <ELIPSIS> (Expression() <THEN> (Action())*)+
}


/* WholeConditionAction */

void WholeConditionAction() : {}
{
    (BooleanExpression() <THEN> (Action())*)+
}


/* OtherwiseAction */

void OtherwiseAction() : {}
{
    <OTHERWISE> [ <THEN> ] (Action())*
}
```

```
/***********************************************************/
/* Operators */

TOKEN :
{
  < EQUALS:     "equals"    |   "equal" |   "="             >
| < EXISTS:     "exists"                |   "exist"         >
| < GT:         "greater than"          |   ">"             >
| < LT:         "less than"             |   "<"             >
| < GE:         "greater than or equal" |   ">="            >
| < LE:         "less than or equal"    |   "<="            >
| < NE:         "<>"                                        >
| < AND:        "and"                                       >
| < OR:         "or"                                        >
| < PLUS:       "plus"                  |   "+"             >
| < MINUS:      "minus"                 |   "-"             >
| < STAR:       "times"                 |   "*"             >
| < SLASH:      "divided by"            |   "/"             >
| < MODULO:     "modulo"                |   "%"             >
}

void AnyOp() : {}
{
    BooleanOp()
|   MathOp()
}

void RelOp() : {}
{
    <EQUALS>
|   <GT>
|   <LT>
|   <GE>
|   <LE>
|   <NE>
}

void BooleanOp() : {}
{
    [ <NOT> ]

    (       RelOp()
        |   <AND>
        |   <OR>
    )
}
```

```
void Exists(): {}
{
    Card() <EXISTS> [ LOOKAHEAD(Location()) Location() ]
}

void MathOp() : {}
{
    <PLUS>
|   <MINUS>
|   <STAR>
|   <SLASH>
|   <MODULO>
}


/************************************************************/
/* BooleanExpression */

void BooleanExpression() : {}
{
        LOOKAHEAD(UnaryBooleanExpression())
            UnaryBooleanExpression()
    |   Operand()   [
                        LOOKAHEAD(BooleanOp() Operand())
                            BooleanOp() Operand()
                    ]
}

void UnaryBooleanExpression() : {}
{
        <NOT> BooleanExpression()
    |   Exists()
}

void HalfBooleanExp() : {}
{
    Operand() BooleanOp()
}
```

```
/***********************************************************/
/* Expression */

SimpleNode Expression() : {}
{
    (
            LOOKAHEAD(UnaryBooleanExpression())
                UnaryBooleanExpression()
        |   Operand()   [ LOOKAHEAD(AnyOp() | <COMMA>)
                             (
                                     AnyOp() Operand()
                           |   ( LOOKAHEAD(2) <COMMA> Operand() )+
                             )
                        ]
    )
        { return jjtThis; }
}

/***********************************************************/
/* Operand */

void Operand() : {}
{
    LOOKAHEAD(<LPAREN> Expression())
        <LPAREN> Expression() <RPAREN>
|   LOOKAHEAD (CardField())
        CardField()
|   Value()
}
```

```
/************************************************************/
/* Value */
TOKEN :
{
    < EMPTY:    "empty" >
}

SimpleNode Value() : {}
{
    (
        Card()
    |   ListOp()
    |   MatchForm()
    |   Literal()
    |   NumericFunction()
    |   AskUserForValue()
    |   <EMPTY>
    )
        { return jjtThis; }
}
/************************************************************/
/* CardSlotValue */
/* Restricted version of Value for stuff that can be */
/* put into a card slot without evaluation */

void SingleCardSlotValue() : {}
{
    <IDENTIFIER>
|   <EMPTY>
|   Literal()
|   <LPAREN> CardSlotValue() <RPAREN>
}

void CardSlotValue() : {}
{
    SingleCardSlotValue() (<COMMA> SingleCardSlotValue())*
}
```

```
/************************************************************/
/* With */
TOKEN :
{
  < WITH:       "with"              >
}

void With() : {}
{
    <WITH> Expression() [ CallingIt() ]
        (Action())*
    <END> <WITH>
}

/************************************************************/
/* CallingIt */
TOKEN :
{
  < CALLING:    "calling"       >
| < IT:         "it"            >
}

void CallingIt() : {}
{
    <CALLING> ( <IT> | <EACH> ) <IDENTIFIER>
}

/************************************************************/
/* MatchForm */
TOKEN :
{
  < CARDS:      "cards"         >
| < THAT:       "that"          >
| < MATCH:      "match"         |   "matching"  >
| < ALL:        "all"           >
}

SimpleNode MatchForm() : {}
{

    (   LOOKAHEAD(3)
                [ <ALL>   ] <CARDS> [ <THAT> ] <MATCH>
          |   [ <MATCH> ] <ALL>   [ <OF>   ]                       )

    (       <LPAREN> MatchDisjunction() <RPAREN>
      |   ( <IDENTIFIER> | Literal() | <CARDS> )
)

    { return jjtThis; }
}
```

```
/***********************************************************/
/* MatchDisjunction */

void MatchDisjunction() : {}
{
    MatchConjunction() ( <OR> MatchConjunction() )*
}

/***********************************************************/
/* MatchConjunction */

void MatchConjunction() : {}
{
    MatchTerm() ( <AND> MatchTerm() )*
}

/***********************************************************/
/* MatchTerm */

void MatchTerm() : {}
{
    LOOKAHEAD(<LPAREN> MatchTerm() <RPAREN>)
        <LPAREN> MatchTerm() <RPAREN>
|   LOOKAHEAD(<IDENTIFIER> RelOp())
        <IDENTIFIER> RelOp() Operand()
|   Operand()
}
```

```
/************************************************************/
/* PickUp */

TOKEN :
{
  < PICKUP:     "pickup"                >
}

void PickUp() : {}
{
    <PICKUP> Value()
}

/************************************************************/
/* PutDown */

TOKEN :
{
  < PUTDOWN:    "putdown"               >
}

void PutDown() : {}
{
    <PUTDOWN> Value() [ Location() ]
}

/************************************************************/
/* Flip */

TOKEN :
{
  < FLIP:   "flip"              >
}

void Flip() : {}
{
    <FLIP> Value()
}
```

```
/***********************************************************/
/* Location */

TOKEN :
{
  < ON:          "on"        >
| < ONTO:        "onto"      >
| < HAND:        "hand"      >
| < TABLE:       "table"     >
| < BOARD:       "board"     >
| < DISCARD:     "discard"   >
| < PILE:        "pile"      >
}

void Location() : {}
{
    [ <IN> | <INTO> | <ON> |  <ONTO> ]
    (
            <HAND>
        |   <TABLE>
        |   <BOARD>
        |   <DISCARD> <PILE>
    )
}

/***********************************************************/
/* Set */

TOKEN :
{
  < SET:         "set"               >
}

void Set() : {}
{
    <SET> CardField() [ <TO> ] Expression()
}
```

```
/************************************************************/
/* Math */

TOKEN :
{
  < ADD:        "add"               >
| < SUBTRACT:   "subtract"          >
| < MULTIPLY:   "multiply"          >
| < DIVIDE:     "divide"            >
| < BY:         "by"                >
}

void Math() : {}
{
    Add()
|   Subtract()
|   Multiply()
|   Divide()
}

void Add() : {}
{
    <ADD> Expression() [ <TO> ] CardField()
}

void Subtract() : {}
{
    <SUBTRACT> Expression() [ <FROM> ] CardField()
}

void Multiply() : {}
{
    <MULTIPLY> CardField() [ <BY> ] Expression()
}

void Divide() : {}
{
    <DIVIDE> CardField() [ <BY> ] Expression()
}
```

```
/************************************************************/
/* List Operators */

TOKEN :
{
  < FIRSTITEM:                "FirstItem"              >
| < ALLBUTFIRSTITEM:          "AllButFirstItem"        >
| < LASTITEM:                 "LastItem"               >
| < ALLBUTLASTITEM:           "AllButLastItem"         >
| < NUMBEROFITEMS:            "NumberOfItems"          >
| < ALLYES:                   "AllYes"                 >
| < ALLNO:                    "AllNo"                  >
| < GREATESTITEM:             "GreatestItem"           >
| < LEASTITEM:                "LeastItem"              >
| < CONCATENATEITEMS:         "ConcatenateItems"       >
| < SUM:                      "Sum"                    >
| < ROUND:                    "Round"                  >
| < SORTEDCOPY:               "SortedCopy"             >
| < SHUFFLEDCOPY:             "ShuffledCopy"           >
| < REVERSEDCOPY:             "ReversedCopy"           >
| < ANYITEMIS:                "AnyItemIs"              >
| < ITEMATPOSITION:           "ItemAtPosition"         >
| < CONNECTEDCOPY:            "ConnectedCopy"          >
| < CARDWITHGREATEST:         "CardWithGreatest"       >
| < CARDWITHLEAST:            "CardWithLeast"          >
| < CARDSSORTEDBY:            "CardsSortedBy"          >
}
```

```
void ListOp() : {}
{
    FirstItem()
|   AllButFirstItem()
|   LastItem()
|   AllButLastItem()
|   NumberOfItems()
|   AllYes()
|   AllNo()
|   GreatestItem()
|   LeastItem()
|   ConcatenateItems()
|   Sum()
|   Round()
|   SortedCopy()
|   ShuffledCopy()
|   ReversedCopy()
|   AnyItemIs()
|   ItemAtPosition()
|   ConnectedCopy()
|   CardWithGreatest()
|   CardWithLeast()
|   CardsSortedBy()
}

void FirstItem() : {}
{
    <FIRSTITEM> [ <IN> | <OF> | <TO> ] Expression()
}

void AllButFirstItem() : {}
{
    <ALLBUTFIRSTITEM> [ <IN> | <OF> | <TO> ] Expression()
}

void LastItem() : {}
{
    <LASTITEM> [ <IN> | <OF> | <TO> ] Expression()
}

void AllButLastItem() : {}
{
    <ALLBUTLASTITEM> [ <IN> | <OF> | <TO> ] Expression()
}

void NumberOfItems() : {}
{
    <NUMBEROFITEMS> [ <IN> | <OF> | <TO> ] Expression()
}
```

```
void AllYes() : {}
{
    <ALLYES> [ <IN> | <OF> | <TO> ] Expression()
}

void AllNo() : {}
{
    <ALLNO> [ <IN> | <OF> | <TO> ] Expression()
}

void GreatestItem() : {}
{
    <GREATESTITEM> [ <IN> | <OF> | <TO> ] Expression()

}

void LeastItem() : {}
{
    <LEASTITEM> [ <IN> | <OF> | <TO> ] Expression()
}

void ConcatenateItems() : {}
{
    <CONCATENATEITEMS> [ <IN> | <OF> | <TO> ] Expression()
}

void Sum() : {}
{
    <SUM> [ <IN> | <OF> | <TO> ] Expression()
}

void Round() : {}
{
    <ROUND> [ <IN> | <OF> | <TO> ] Expression()
}

void SortedCopy() : {}
{
    <SORTEDCOPY> [ <IN> | <OF> | <TO> ] Expression()
}

void ShuffledCopy() : {}
{
    <SHUFFLEDCOPY> [ <IN> | <OF> | <TO> ] Expression()
}

void ReversedCopy() : {}
{
    <REVERSEDCOPY> [ <IN> | <OF> | <TO> ] Expression()
}
```

```
void AnyItemIs() : {}
{
    <ANYITEMIS> Expression() [ <IN> | <OF> | <TO> ] Expression()
}

void ItemAtPosition() : {}
{
    <ITEMATPOSITION> Expression() [ <IN> | <OF> | <TO> ] Expres-
sion()
}

void ConnectedCopy() : {}
{
   <CONNECTEDCOPY> Expression() [ <IN> | <OF> | <TO> ] Expression()
}

void CardWithGreatest() : {}
{
    <CARDWITHGREATEST> Field() [ <IN> | <OF> | <TO> ] Value()
}

void CardWithLeast() : {}
{
    <CARDWITHLEAST> Field() [ <IN> | <OF> | <TO> ] Value()
}

void CardsSortedBy() : {}
{
    <CARDSSORTEDBY> Field() [ <IN> | <OF> | <TO> ] Value()
}


/************************************************************/
/* ListStatement */

TOKEN :
{
  < APPEND:     "append"                >
}

void ListStatement() : {}
{
    Append()
}

void Append() : {}
{
    <APPEND> Expression() [ <TO> ] CardField()
}
```

```
/************************************************************/
/* Numeric Functions */

TOKEN :
{
  < RANDOM:             "Random"                >
}

void NumericFunction() : {}
{
    Random()
}

void Random() : {}
{
    <RANDOM> [<FROM>] Expression() [<TO>] Expression()
}

/************************************************************/
/* Ask User */

TOKEN :
{
  < ASK:        "Ask"       >
}

void AskUserForValue() : {}
{
    <ASK> StringOrIdentifier()
}

/************************************************************/
/* Tell User */

TOKEN :
{
  < TELL:       "tell"      >
}

void TellUser() : {}
{
    <TELL> Expression()
}
```

```
/************************************************************/
/* Make */

TOKEN :
{
  < MAKE:       "make"      >
}

void Make() : {}
{
    <MAKE> CardFactory()
}

/************************************************************/
/* Beep */

TOKEN :
{
  < BEEP:       "beep"      >
}

void Beep() : {}
{
    <BEEP>
}
```

```
/************************************************************/
/* Literal */

TOKEN :
{
  < INTEGER_LITERAL: ("-")? (["0"-"9"])+ >
|
  < FLOATING_POINT_LITERAL:
        ("-")? (["0"-"9"])+ "." (["0"-"9"])* (<EXPONENT>)?
      | ("-")? "." (["0"-"9"])+ (<EXPONENT>)?
      | ("-")? (["0"-"9"])+ (<EXPONENT>)?
  >
|
  < #EXPONENT: ["e","E"] (["+","-"])? (["0"-"9"])+ >
|
  < STRING_LITERAL:
      "\"" (~["\"","\\","\n","\r"])* "\""               // "string"
|      "`" (~["`","\\","\n","\r"])* "`"                 // `string`
|      "“" (~["“","”","\\","\n","\r"])* "”"             // “string”
|      "‘" (~["‘","’","\\","\n","\r"])* "’"             // ‘string’
  >
| < TRUE: "yes" >
| < FALSE: "no" >
}

void Literal() : {}
{
    <INTEGER_LITERAL>
|   <FLOATING_POINT_LITERAL>
|   <STRING_LITERAL>
|   <TRUE>
|   <FALSE>
}

SimpleNode StringOrIdentifier() : {}
{
    (   <STRING_LITERAL>
    |   <IDENTIFIER>
    )
        { return jjtThis; }
}
```

```
/************************************************************/
/* IDENTIFIERS */

TOKEN :
{
  < IDENTIFIER: <SIMPLE_IDENTIFIER> | <DELIMITED_IDENTIFIER> >
|
  < #SIMPLE_IDENTIFIER: <LETTER> (<LETTER>|<DIGIT>|"-"|"_"|"/
"|".")* >
|
  < #DELIMITED_IDENTIFIER: "|" (~["|","\\","\n","\r"])* "|" >
|
  < #LETTER: ["a"-"z","A"-"Z"] >
|
  < #DIGIT: ["0"-"9"] >
}

/************************************************************/
/* COMMENTS */
MORE :
{
  "//" : IN_SINGLE_LINE_COMMENT
| <"/**" ~["/"]> { input_stream.backup(1); } : IN_FORMAL_COMMENT
| "/*" : IN_MULTI_LINE_COMMENT
}

<IN_SINGLE_LINE_COMMENT>
SPECIAL_TOKEN :
{
  <SINGLE_LINE_COMMENT: "\n" | "\r" | "\r\n" > : DEFAULT
}

<IN_FORMAL_COMMENT>
SPECIAL_TOKEN :
{
  <FORMAL_COMMENT: "*/" > : DEFAULT
}

<IN_MULTI_LINE_COMMENT>
SPECIAL_TOKEN :
{
  <MULTI_LINE_COMMENT: "*/" > : DEFAULT
}

<IN_SINGLE_LINE_COMMENT,IN_FORMAL_COMMENT,IN_MULTI_LINE_COMMENT>
MORE :
{
  < ~[] >
}
```

APPENDIX B Example Programs

This appendix contains the full source code for several HANDS programs.

2.1 Breakout

This implementation of Breakout was developed by an undergraduate student who worked on the project for a semester. It is pictured in Figure 2-1.

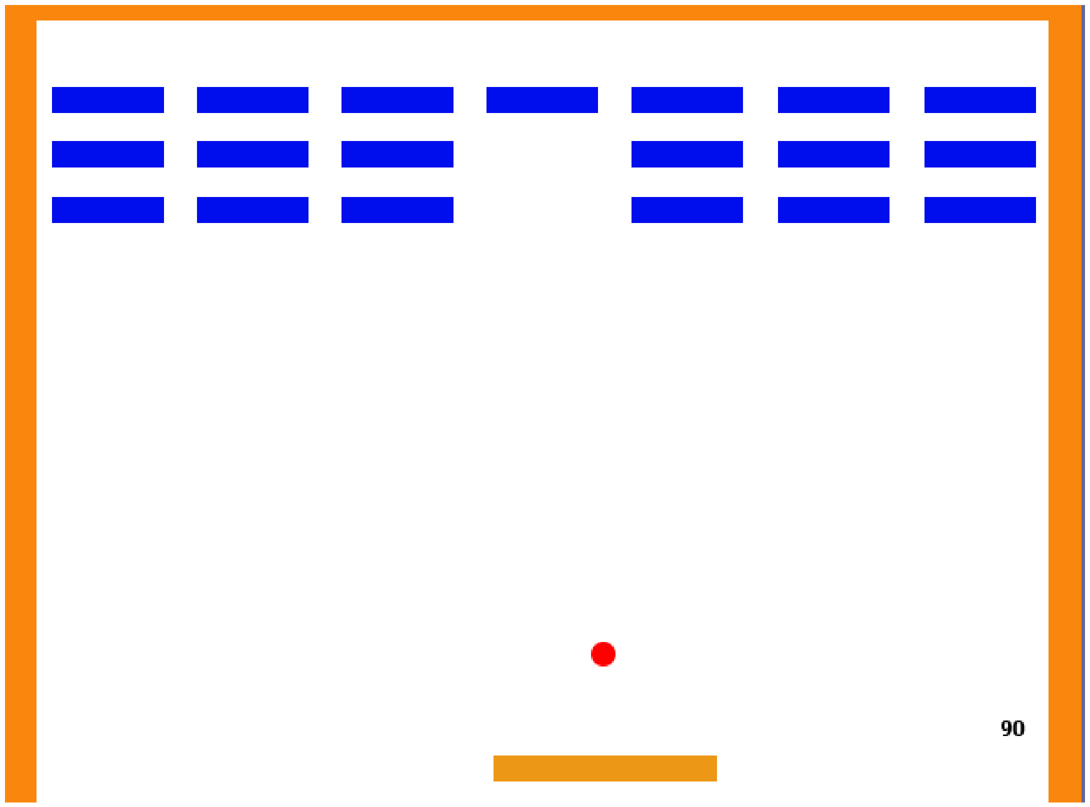


Figure 2-1. A version of the game Breakout, implemented in HANDS.

```
b1 x:225 y:63 hits:-1 back:gamegfx/blueblock.gif group:block;
b13 x:225 y:94 hits:-1 back:gamegfx/blueblock.gif group:block;
b14 x:225 y:126 hits:-1 back:gamegfx/blueblock.gif group:block;
b15 x:308 y:63 hits:-1 back:gamegfx/blueblock.gif group:block;
b16 x:308 y:94 hits:-1 back:gamegfx/blueblock.gif group:block;
b17 x:308 y:126 hits:-1 back:gamegfx/blueblock.gif group:block;
b18 x:391 y:63 hits:-1 back:gamegfx/blueblock.gif group:block;
b19 x:391 y:94 hits:-1 back:gamegfx/blueblock.gif group:block;
b2 x:391 y:126 hits:-1 back:gamegfx/blueblock.gif group:block;
b20 x:474 y:63 hits:-1 back:gamegfx/blueblock.gif group:block;
b21 x:474 y:94 hits:-1 back:gamegfx/blueblock.gif group:block;
b22 x:474 y:126 hits:-1 back:gamegfx/blueblock.gif group:block;
b23 x:557 y:63 hits:-1 back:gamegfx/blueblock.gif group:block;
b24 x:557 y:94 hits:-1 back:gamegfx/blueblock.gif group:block;
b3 x:557 y:126 hits:-1 back:gamegfx/blueblock.gif group:block;
b4 x:641 y:63 hits:-1 back:gamegfx/blueblock.gif group:block;
b5 x:641 y:94 hits:-1 back:gamegfx/blueblock.gif group:block;
b6 x:641 y:126 hits:-1 back:gamegfx/blueblock.gif group:block;
b7 x:725 y:63 hits:-1 back:gamegfx/blueblock.gif group:block;
b8 x:725 y:94 hits:-1 back:gamegfx/blueblock.gif group:block;
```

```
b9 x:725 y:126 hits:-1 back:gamegfx/blueblock.gif group:block;
ball x:473.0 y:70.0 back:gamegfx/bullet.gif group:pellet direction:90 speed:10
stopped:0;
dirdisplay x:768 y:423 back:90;
l2b1 x:732 y:53 hits:2 back:gamegfx/greyblock.gif group:l2block hitpoints:2;
l2b1-copy10 x:665 y:53 hits:2 back:gamegfx/greyblock.gif group:l2block hitpoints:2;
l2b1-copy11 x:598 y:53 hits:2 back:gamegfx/greyblock.gif group:l2block hitpoints:2;
l2b1-copy12 x:531 y:53 hits:2 back:gamegfx/greyblock.gif group:l2block hitpoints:2;
l2b1-copy13 x:464 y:53 hits:2 back:gamegfx/greyblock.gif group:l2block hitpoints:2;
l2b1-copy14 x:397 y:53 hits:2 back:gamegfx/greyblock.gif group:l2block hitpoints:2;
l2b1-copy15 x:330 y:53 hits:2 back:gamegfx/greyblock.gif group:l2block hitpoints:2;
l2b1-copy16 x:263 y:53 hits:2 back:gamegfx/greyblock.gif group:l2block hitpoints:2;
l2b1-copy17 x:216 y:137 hits:2 back:gamegfx/greyblock.gif group:l2block hitpoints:2;
l2b1-copy18 x:283 y:137 hits:2 back:gamegfx/greyblock.gif group:l2block hitpoints:2;
l2b1-copy19 x:350 y:137 hits:2 back:gamegfx/greyblock.gif group:l2block hitpoints:2;
l2b1-copy2 x:10 y:800 hits:-1 back:gamegfx/greyblock.gif group:l2block hitpoints:2;
l2b1-copy20 x:484 y:137 hits:2 back:gamegfx/greyblock.gif group:l2block hitpoints:2;
l2b1-copy21 x:685 y:137 hits:2 back:gamegfx/greyblock.gif group:l2block hitpoints:2;
l2b1-copy22 x:618 y:137 hits:2 back:gamegfx/greyblock.gif group:l2block hitpoints:2;
l2b1-copy23 x:551 y:137 hits:2 back:gamegfx/greyblock.gif group:l2block hitpoints:2;
l2b1-copy24 x:330 y:221 hits:2 back:gamegfx/greyblock.gif group:l2block hitpoints:2;
l2b1-copy25 x:263 y:221 hits:2 back:gamegfx/greyblock.gif group:l2block hitpoints:2;
l2b1-copy26 x:732 y:221 hits:2 back:gamegfx/greyblock.gif group:l2block hitpoints:2;
l2b1-copy27 x:665 y:221 hits:2 back:gamegfx/greyblock.gif group:l2block hitpoints:2;
l2b1-copy28 x:598 y:221 hits:2 back:gamegfx/greyblock.gif group:l2block hitpoints:2;
l2b1-copy29 x:531 y:221 hits:2 back:gamegfx/greyblock.gif group:l2block hitpoints:2;
l2b1-copy3 x:10 y:800 hits:-1 back:gamegfx/greyblock.gif group:l2block hitpoints:2;
l2b1-copy30 x:397 y:221 hits:2 back:gamegfx/greyblock.gif group:l2block hitpoints:2;
l2b1-copy31 x:283 y:305 hits:2 back:gamegfx/greyblock.gif group:l2block hitpoints:2;
l2b1-copy4 x:350 y:305 hits:2 back:gamegfx/greyblock.gif group:l2block hitpoints:2;
l2b1-copy5 x:10 y:800 hits:-1 back:gamegfx/greyblock.gif group:l2block hitpoints:2;
l2b1-copy6 x:484 y:305 hits:2 back:gamegfx/greyblock.gif group:l2block hitpoints:2;
l2b1-copy7 x:551 y:305 hits:2 back:gamegfx/greyblock.gif group:l2block hitpoints:2;
l2b1-copy8 x:618 y:305 hits:2 back:gamegfx/greyblock.gif group:l2block hitpoints:2;
l2b1-copy9 x:685 y:305 hits:2 back:gamegfx/greyblock.gif group:l2block hitpoints:2;
l2b2 x:216 y:305 hits:2 back:gamegfx/greyblock.gif group:l2block hitpoints:2;
leftwall x:196 y:10 back:gamegfx/sidewall.gif group:lwall;
level1 x:97 y:441 xlist:225, 225, 225, 308, 308, 308, 391, 391, 391, 474, 474, 474, 557,
557, 557, 641, 641, 641, 725, 725, 725 ylist:63, 94, 126, 63, 94, 126, 63, 94, 126, 63,
94, 126, 63, 94, 126, 63, 94, 126, 63, 94, 126 numblocks:21;
level2 x:832 y:328 xlist:732, 665, 598, 531, 464, 397, 330, 263, 216, 283, 350, 417,
484, 685, 618, 551, 330, 263, 732, 665, 598, 531, 464, 397, 283, 350, 417, 484, 551,
618, 685, 216 ylist:53, 53, 53, 53, 53, 53, 53, 53, 137, 137, 137, 137, 137, 137, 137,
137, 221, 221, 221, 221, 221, 221, 221, 221, 305, 305, 305, 305, 305, 305, 305, 305
numblocks:32;
paddle x:418.0 y:446 back:gamegfx/bar.gif speed:0 direction:180 group:striker;
rightwall x:796 y:8 back:gamegfx/sidewall.gif group:rwall;
topwall x:193 y:5 back:gamegfx/topwall.gif group:twall;
vars x:833 y:185 speed:10 startx:478 starty:430 bstartx:533 tmp:31 tmp2:0.5 calc:64
dir:90 currlevel:2 blocksgone:0;
when " " is typed

    if ball's stopped then

        set ball's direction to 90

        set ball's speed to vars's speed

        set ball's stopped to 0
    end if

end when
when anything happens
     if paddle's x < (leftwall's x + 20) then
          set paddle's speed to 0
          set paddle's x to leftwall's x + 20

          if ball's stopped then
                    set ball's speed to 0
                    set ball's x to paddle's x + 56
          end if
     end if
     if (paddle's x + 128) > rightwall's x then
          set paddle's speed to 0
          set paddle's x to rightwall's x - 128
          if ball's stopped then
                    set ball's speed to 0
       set ball's x to paddle's x + 56
          end if
     end if

     if ball's y > 460 then
          set ball's speed to 0
          set paddle's speed to 0
          set ball's direction to paddle's direction
          set ball's x to paddle's x
          set ball's y to paddle's y
          set ball's stopped to yes
          add 55 to ball's x
          subtract 10 from ball's y
     end if

            if vars's currlevel equals 1 then
                   if vars's blocksgone = level1's numblocks then
                          set vars's currlevel to 2
                                 set vars's blocksgone to 0
                          set x of all l2blocks to level2's xlist
                          set y of all l2blocks to level2's ylist
                                 set hits of all l2blocks to 2
                             putdown all l2blocks
                     set paddle's speed to 0
                     set paddle's direction to 0
                     set paddle's x to vars's startx
                     set ball's x to vars's bstartx
                     set ball's y to vars's starty
                  set ball's stopped to yes
                        set ball's speed to 0
                            set ball's direction to 90
            end if
            end if

end when
when ball collides into any block
       //set ball's direction to ( 0 - ball's direction )

       if ball's direction < 0 then
              add 360 to ball's direction
       ball's direction > 360 then
              subtract 360 from ball's direction
       end if
       if ball's y > block's y then
    if ball's direction < 180 then //ball is moving up
               set ball's direction to (0 - ball's direction)
              ball's direction > 180 then
                   set ball's direction to (0 - ball's direction)
    end if

    ball's y < block's y then
           if ball's direction > 180 then //ball is moving down
        set ball's direction to (0 - ball's direction)
    ball's direction < 180 then
        set ball's direction to (0 - ball's direction)
    end if
end if

       subtract 1 from block's hits
       if block's hits < 0 then
                          //set block's x to 10
                     //set block's y to 800
            pickup block
            add 1 to vars's blocksgone
       end if


end when
when ball collides into any l2block
       if ball's direction < 0 then
              add 360 to ball's direction
       ball's direction > 360 then
              subtract 360 from ball's direction
       end if
//set ball's direction to ( 0 - ball's direction )
       if ball's y > l2block's y then
    if ball's direction < 180 then //ball is moving up
               set ball's direction to (0 - ball's direction)
              ball's direction > 180 then
                   set ball's direction to (0 - ball's direction)
    end if

    ball's y < l2block's y then
           if ball's direction > 180 then //ball is moving down
        set ball's direction to (0 - ball's direction)
    ball's direction < 180 then
        set ball's direction to (0 - ball's direction)
    end if
end if
       subtract 1 from l2block's hits
       if l2block's hits < 0 then
              set l2block's x to 10
              set l2block's y to 800
       end if
       beep

end when
when ball collides into any lwall
       if ball's direction < 0 then
```

```
              add 360 to ball's direction
       ball's direction > 360 then
              subtract 360 from ball's direction
       end if
                   set ball's direction to (180 - ball's direction)

end when
when ball collides into any rwall
       if ball's direction < 0 then
              add 360 to ball's direction
       ball's direction > 360 then
              subtract 360 from ball's direction
       end if
                   set ball's direction to (180 - ball's direction)

end when
when ball collides into any striker
       if ball's direction < 0 then
              add 360 to ball's direction
       ball's direction > 360 then
              subtract 360 from ball's direction
       end if
           set vars's calc to ((ball's x+8) - paddle's x) + 1
           set vars's tmp2 to (vars's calc / 128)
           set ball's direction to 150 - (vars's tmp2 * 120    )
           set vars's dir to (vars's tmp2 * 180)

end when
when ball collides into any twall
       if ball's direction < 0 then
              add 360 to ball's direction
       ball's direction > 360 then
              subtract 360 from ball's direction
       end if
    set ball's direction to (0 - ball's direction)

end when
when j is typed
    set paddle's speed to vars's speed
    set paddle's direction to 180
    if ball's stopped then
        set ball's direction to 180
        set ball's speed to vars's speed
    end if
end when
when k is typed
    set paddle's speed to 0
    if ball's stopped then
        set ball's speed to 0
    end if
end when
when l is typed
    set paddle's direction to 0
    set paddle's speed to vars's speed
    if ball's stopped then
        set ball's direction to 0
        set ball's speed to vars's speed
    end if
end when
```

```
when program starts running
       set paddle's speed to 0
       set paddle's direction to 0
       set paddle's x to vars's startx
       set ball's x to vars's bstartx
       set ball's y to vars's starty
         set ball's stopped to yes
       set ball's speed to 0
       set ball's direction to 90
       set x of all blocks to level1's xlist
       set y of all blocks to level1's ylist
       set x of all l2blocks to level2's xlist
set y of all l2blocks to level2's ylist
pickup all l2blocks
       set hits of all blocks to 0
set vars's currlevel to 1
set vars's blocksgone to 0
putdown all blocks


end when
```

2.2 Ideal Gas Law Simulation

This simulation of the ideal gas law (PV=nRT) was developed also by the undergraduate student who worked on the project. It is pictured in Figure 2-2.

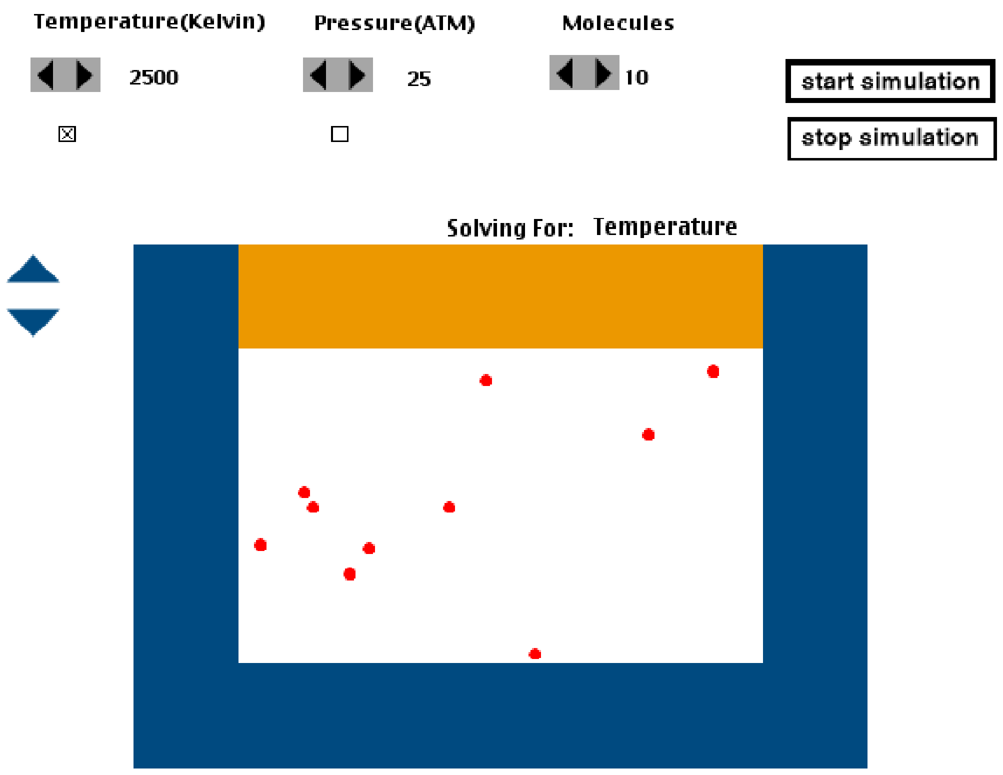


Figure 2-2. Simulation of the ideal gas law, as implemented in HANDS.

```
mup x:539 y:37 back:rarrow.gif;
startsim x:654 y:39 back:startsim.gif started:yes;
stopsim x:655 y:72 back:stopsim.gif;
plunger x:281 y:145 back:topbar.gif kind:twall;
pressure x:437 y:43 back:25 value:25;
varlabel x:460 y:128 back:"Solving For:";
temperature x:278 y:42 value:250 back:2500;
templabel x:224 y:10 back:"Temperature(Kelvin)";
rightbar x:641 y:145 back:sidebar.gif kind:rwall;
pressurelabel x:384 y:11 back:"Pressure(ATM)";
mdown x:519 y:37 back:larrow.gif;
plungedown x:202 y:179 back:downarrow.gif;
plungeup x:202 y:148 back:uparrow.gif;
pdown x:378 y:38 back:larrow.gif;
checktemp x:238 y:77 back:checked.gif value:Temperature;
spdup x:242 y:38 back:rarrow.gif;
ball9 x:629.2444436971679 y:217.17885848290894 back:atom.gif kind:atom direction:-15
speed:2.5;
ball8 x:507.8705096681376 y:238.09711653795102 back:atom.gif kind:atom direction:-281
speed:2.5;
Volume x:17 y:288 value:100 clicks:9;
```

```
pup x:398 y:38 back:rarrow.gif;
ball7 x:409.2927629895068 y:286.03758763614337 back:atom.gif kind:atom direction:-145
speed:2.5;
ball6 x:433.87130342154995 y:321.648639764889 back:atom.gif kind:atom direction:-166
speed:2.5;
ball5 x:554.6022135871442 y:227.35969321380009 back:atom.gif kind:atom direction:-311
speed:2.5;
ball4 x:530.2741598317327 y:363.26249490033297 back:atom.gif kind:atom direction:-266
speed:2.5;
ball3 x:388.61072229560267 y:222.15690535994378 back:atom.gif kind:atom direction:-278
speed:2.5;
variable x:544 y:127 back:Temperature;
bottombar x:281 y:385 back:bottombar.gif kind:bwall;
checkpressure x:394 y:77 back:unchecked.gif value:Pressure;
molecules x:561 y:42 value:10 back:10;
vars x:819 y:271 miny:145 maxy:300 initialspeed:3 x1:341 x2:630 y1:205 y2:375 total-
startspeed:30 numballs:10 totalspeed:7.5 entropy:0;
leftbar x:281 y:145 back:sidebar.gif kind:lwall;
spddown x:222 y:38 back:larrow.gif;
ball26 x:463.7398089978607 y:240.84388539871472 back:atom.gif kind:atom direction:45
speed:2.5;
ball25 x:548.8096781445022 y:215.80798793768787 back:atom.gif kind:atom direction:33
speed:2.5;
numlabel x:526 y:11 back:Molecules;
ball24 x:349.5534615327548 y:289.05100908957604 back:atom.gif kind:atom direction:-112
speed:2.5;
when any atom collides into any bwall
       if atom's direction < 0 then
              add 360 to atom's direction
       atom's direction > 360 then
              subtract 360 from atom's direction
       end if
       set atom's direction to ( 0 - atom's direction )
end when
when any atom collides into any lwall
       if atom's direction < 0 then
              add 360 to atom's direction
       atom's direction > 360 then
              subtract 360 from atom's direction
       end if

       set atom's direction to (180 - atom's direction)
end when
when any atom collides into any plunger
       if atom's direction < 0 then
              add 360 to atom's direction
       atom's direction > 360 then
              subtract 360 from atom's direction
       end if
       if (atom's direction < 180) and (atom's direction > 0) then
              set atom's direction to ( 0 - atom's direction )
       end if
end when
when any atom collides into any rwall
       if atom's direction < 0 then
              add 360 to atom's direction
       atom's direction > 360 then
              subtract 360 from atom's direction
       end if
       set atom's direction to (180 - atom's direction)

end when
when anything happens
/* Luis Cota - lcota@andrew.cmu.edu
    Fall 2001
    bap bap I wrote this

    ***General Program Notes***

    Whenever a variable gets changed, the entire system is stopped
           and the equation pv=nrt is re-evaluated. Only one variable can
    be unknown at any given time otherwise a solution cannot be
    found. In order to force this, a selection must be made by the
    user (otherwise a default is chosen). This selection determines
           which variable this code solves for. The variables the code will
    solve for are Pressure and Temperature ONLY.

           The reason for this is that this equation assumes knowledge of
           N , R, and V. Then, a Pressure OR a Temperature are chosen
           and the unknown variable can be solved for through simple
    algebra. This is why the system must be re-evaluated each
    time a variable changes.

*/



end when
when checkpressure clicked
    set checkpressure's back to checked.gif
    set checktemp's back to unchecked.gif
           set back of variable to Pressure

end when
when checktemp clicked
                  set checktemp's back to checked.gif
           set checkpressure's back to unchecked.gif
           set back of variable to Temperature
end when
when mdown is clicked
       if(molecules's value > 0) then
              putdown FirstItem all atoms on discard pile
              subtract 1 from molecules's value
       end if
set molecules's back to molecules's value
set speed of all atoms to (temperature's value / (10*molecules's value))
end when
when mup clicked
       add 1 to molecules's value
       set molecules's back to molecules's value
       with duplicate of (FirstItem all atoms) calling each b
              set b's direction to random from 0 to 359
              set b's x to random from vars's x1 to vars's x2
              set b's y to random from  (plunger's y+61) to vars's y2
              set b's cardname to ("ball" + molecules's value)
       end with
set speed of all atoms to (temperature's value / (10*molecules's value))
```

```
end when
when pdown clicked
       if pressure's value > 1 then
              subtract 1 from pressure's value
       pressure's value = 1 then
              set pressure's value to 1
       end if
       set pressure's back to pressure's value
end when
when plungedown clicked

       if volume's clicks > 0 then
    add 10 to plunger's y
    subtract 10 from volume's value
    subtract 1 from volume's clicks
end if

if startsim's started then
putdown all atoms
/*with all atoms calling each a
    set direction of a to random from 0 to 360
end with
*/
if /* begin case statement */
    checktemp's back = checked.gif then
               set temperature's value to (pressure's value * volume's value)
             set temperature's value to (temperature's value / molecules's value)
                     set temperature's value to temperature's value
               set temperature's back to (temperature's value * 10)
              set speed of all atoms to (temperature's value / (molecules's value * 10))

    checktemp's back = unchecked.gif then
        if
            temperature's value <= 0 then
                set speed of all atoms to 0

            temperature's value > 0 then
                set pressure's value to (molecules's value * temperature's value)
                set pressure's value to (pressure's value / volume's value)
                set pressure's back to pressure's value
              set speed of all atoms to (temperature's value / (molecules's value * 10))
        end if
       end if
end if
end when
when plungeup clicked

if volume's clicks < 9 then
    subtract 10 from plunger's y
    add 10 to volume's value
    add 1 to volume's clicks
end if

if startsim's started then
putdown all atoms
/*with all atoms calling each a
    set direction of a to random from 0 to 360
end with
*/
```

```
if /* begin case statement */
    checktemp's back = checked.gif then
               set temperature's value to (pressure's value * volume's value)
             set temperature's value to (temperature's value / molecules's value)
       set temperature's value to temperature's value
               set temperature's back to (temperature's value * 10)
              set speed of all atoms to (temperature's value / (molecules's value * 10))

    checktemp's back = unchecked.gif then
        if
            temperature's value <= 0 then
                set speed of all atoms to 0

            temperature's value > 0 then
                set pressure's value to (molecules's value * temperature's value)
                set pressure's value to (pressure's value / volume's value)
                set pressure's back to pressure's value
              set speed of all atoms to (temperature's value / (molecules's value * 10))
        end if
       end if
end if
end when
when program starts
    pickup all atoms
    set molecules's value to NumberOfItems all atoms
    set molecules's back to molecules's value
    set startsim's started to no
end when
/*
       when pressure is changed...the other values are taken and held as constant
       and the system will be reevaluated
*/
when pup clicked
       add 1 to pressure's value
       set pressure's back to pressure's value
end when
/*
       when speed is modified, all the other values are held constant
       and the system is recalculated ...
*/
when spddown clicked
       if (temperature's value - 5) <= 0 then
              set temperature's value to 0
        (temperature's value) >= 5 then
              subtract 5 from temperature's value
       end if

       set back of temperature to (temperature's value *10)
end when
/*
       when speed is modified, all the other values are held constant
       and the system is recalculated ...
*/
when spdup clicked
       add 5 to temperature's value
       set temperature's back to (temperature's value * 10)
end when
when startsim clicked
```

```
putdown all atoms
set startsim's started to yes
with all atoms calling each a
    set direction of a to random from 0 to 360
           set a's x to random from vars's x1 to vars's x2
           set a's y to random from (plunger's y + 61) to vars's y2
end with

if /* begin case statement */
    checktemp's back = checked.gif then
               set temperature's value to (pressure's value * volume's value)
             set temperature's value to (temperature's value / molecules's value)
set temperature's value to temperature's value

               set temperature's back to (temperature's value *10)
              set speed of all atoms to (temperature's value / (molecules's value * 10))

    checktemp's back = unchecked.gif then
        if
            temperature's value <= 0 then
                set speed of all atoms to 0

            temperature's value > 0 then
                set pressure's value to (molecules's value * temperature's value)
                set pressure's value to (pressure's value / volume's value)
                set pressure's back to pressure's value
              set speed of all atoms to (temperature's value / (molecules's value * 10))
        end if
       end if
end when
when stopsim clicked
    set speed of all atoms to 0

end when
```

2.3 Towers of Hanoi

I implemented this solution to Towers of Hanoi, pictured in Figure 2-3.

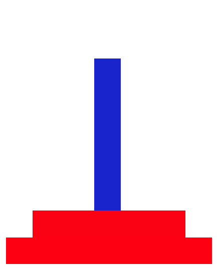
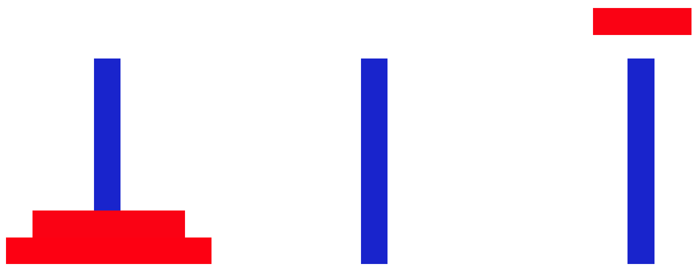



Figure 2-3. A solution to the Towers of Hanoi problem, as implemented in HANDS.

```
bottom x:199 y:269 kind:hwall back:invisible-boundary-horiz.gif;
dropper x:583 y:125 back:invisible-dot.gif;
goal x:212 y:528 sequence:(small-ring, medium-ring, large-ring), h-tower1, h-tower2, h-
tower3 ring:empty destination:empty spare:empty source:empty;
h-tower1 x:360 y:192 back:tower.jpg kind:tower;
h-tower2 x:460 y:192 back:tower.jpg kind:tower;
h-tower3 x:560 y:192 back:tower.jpg kind:tower;
large-ring x:327.0 y:259.0 back:bigdisk.jpg kind:ring direction:270 speed:0 dropEast:43
dropWest:-33;
medium-ring x:337.0 y:249 back:meddisk.jpg kind:ring direction:270 speed:0 dropEast:33
dropWest:-23;
small-ring x:347.0 y:239 back:smdisk.jpg kind:ring direction:270 speed:0 dropEast:23
dropWest:-13;
top x:199 y:120 kind:hwall back:invisible-boundary-horiz.gif;
when any ring collides into any ring
       set the first-ring's speed to 0
       set goal's ring to empty
end when
when any ring collides into bottom
       set the ring's speed to 0
       set goal's ring to empty
end when
when any ring collides into dropper
       set direction of the ring to 270
end when
when any ring collides into top
       if (x of ring) < (x of goal's destination) then
              set ring's direction to 0
              set dropper's x to (x of goal's destination) + (ring's dropEast)
       otherwise
              set ring's direction to 180
              set dropper's x to (x of goal's destination) + (ring's dropWest)
       end if
end when
when goal changes
       if (goal's ring = empty) then
              set goal's ring to FirstItem goal's sequence
              set goal's sequence to AllButFirstItem goal's sequence
              set goal's source to FirstItem goal's sequence
              set goal's sequence to AllButFirstItem goal's sequence
              set goal's spare to FirstItem goal's sequence
              set goal's sequence to AllButFirstItem goal's sequence
              set goal's destination to FirstItem goal's sequence
              set goal's sequence to AllButFirstItem goal's sequence
       end if
       if (NumberOfItems in goal's ring) > 1 then
              set goal's sequence to
                     (AllButLastItem in goal's ring), goal's source, goal's destina-
tion, goal's spare,
                     (LastItem in goal's ring), goal's source, goal's spare, goal's des-
tination,
                     (AllButLastItem in goal's ring), goal's spare, goal's source,
goal's destination,
                     goal's sequence
              set goal's ring to empty
          (NumberOfItems in goal's ring) = 1 then
              set direction of (goal's ring) to 90
              set speed of (goal's ring) to 2
       end if
end when
when program starts
       // touch goal, to fire a "goal changes" event
       set goal's ring to goal's ring
end when
```

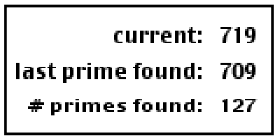
2.3.1 Extension to Towers of Hanoi

The following program can be imported into the above program, to change it to a four-disk problem.

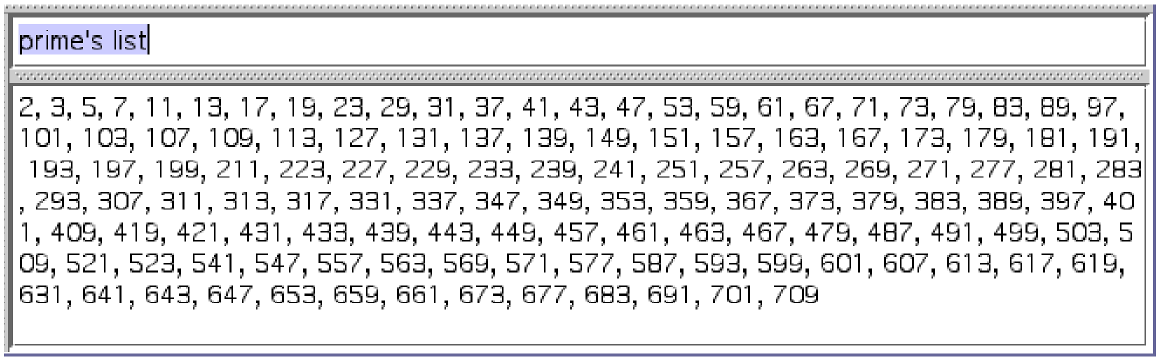
```
goal x:212 y:528 sequence:(mini-ring, small-ring, medium-ring, large-ring), h-tower1,
h-tower2, h-tower3 ring:empty destination:empty spare:empty source:empty;
mini-ring x:357.0 y:229 back:minidisk.jpg kind:ring direction:270 speed:0 dropEast:13
dropWest:-3;
```

2.4 Primes Sieve

I wrote this program to compute prime numbers using a sieve technique. Figure 2-4 shows the state of the program after it has run for a while, while the code below shows its initial state.



```
          current:  719
last prime found:  709
  # primes found:  127
```



```
prime's list
```

```
2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, 41, 43, 47, 53, 59, 61, 67, 71, 73, 79, 83, 89, 97,
101, 103, 107, 109, 113, 127, 131, 137, 139, 149, 151, 157, 163, 167, 173, 179, 181, 191,
 193, 197, 199, 211, 223, 227, 229, 233, 239, 241, 251, 257, 263, 269, 271, 277, 281, 283
, 293, 307, 311, 313, 317, 331, 337, 347, 349, 353, 359, 367, 373, 379, 383, 389, 397, 40
1, 409, 419, 421, 431, 433, 439, 443, 449, 457, 461, 463, 467, 479, 487, 491, 499, 503, 5
09, 521, 523, 541, 547, 557, 563, 569, 571, 577, 587, 593, 599, 601, 607, 613, 617, 619,
631, 641, 643, 647, 653, 659, 661, 673, 677, 683, 691, 701, 709
```

Figure 2-4. The top of this figure shows the screen of a program that computes prime numbers using a sieve technique, as implemented in HANDS. The bottom of this figure shows the primes that have been computed so far, which are stored in the `list` property of the card `prime`.

```
count x:321 y:110 back:1;
count-label x:212 y:110 back:"# primes found:";
current x:321 y:70 back:3;
current-label x:260 y:70 back:"current:";
prime x:321 y:90 back:2 list:2;
primes-label x:204 y:90 back:"last prime found:";
when nothing happens
       if not AnyItemIs 0 in (current's back % prime's list) then
              append current's back to prime's list
              set prime's back to current's back
              add 1 to count's back
       end if
       add 2 to current's back
end when
```

2.5 Compass

This compass card can be imported into any program, to give the user symbolic access to some common directions, such as `compass’s north`.

```
compass x:873 y:589 back:compass.gif north:90 south:270 east:0 west:180 up:90 down:270
left:180 right:0 northeast:45 northwest:135 southeast:315 southwest:225;
```

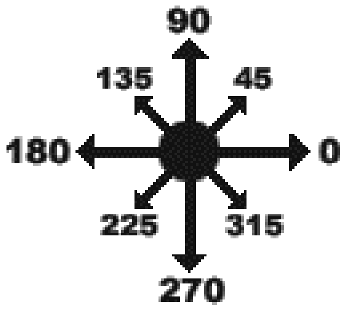


Figure 2-5. This compass card contains properties for various directions, such as `compass's north`.

2.6 Boundaries

This boundaries program can be imported into any program, to cause all objects to bounce when they reach the edge of the board. Without this program, the objects would continue moving off the board.

```
bottom x:199 y:473 kind:hwall back:invisible-boundary-horiz.gif;
left x:198 y:16 kind:vwall back:invisible-boundary-vert.gif;
right x:815 y:16 kind:vwall back:invisible-boundary-vert.gif;
top x:199 y:17 kind:hwall back:invisible-boundary-horiz.gif;
when any hwall collides
        // hwall never moves, so "firstitem in event's value" is always the other card
        with firstitem in event's value calling each the object
                set direction of the object to (360 - direction of the object)
        end with
end when
when any vwall collides
        // vwall never moves, so "firstitem in event's value" is always the other card
        with firstitem in event's value calling each the object
                set direction of the object to (180 - direction of the object)
        end with
end when
```

2.7 Trap Door

This trap door program can be imported into any program. When an object collides into the invisible trap door, it is moved to a new location, specified in the `destination-x` and `destination-y` coordinates.

```
trapdoor x:734 y:423 kind:trapdoor destination-x:250 destination-y:100 back:invisible-
dot.gif;
when any trapdoor collides
        // trapdoor never moves,
        // so "firstitem in event's value"
        // is always the other card
        with firstitem in event's value calling each the object
                set x of the object to destination-x of trapdoor
                set y of the object to destination-y of trapdoor
        end with
end when
```

APPENDIX C Background Research

This appendix contains the full text of my technical report surveying usability issues in the design of programming systems for beginners [Pane, 1996 #295].

1. Introduction

This report summarizes research about novice programming. Over the past twenty years many research studies have discovered useful information about novice programmers, and identified good and bad aspects of today's programming systems[1], both visual and textual. However, this body of research is widely distributed throughout the literature and is not well organized, making it difficult to use in guiding the design of new systems. The result is that these research results generally have not been systematically fed back into the design of new programming systems. Instead, the design of new languages and environments has most often been driven by technical objectives, such as ease of parsing, ease of generating fast code, closeness to the machine, ease of proving correctness, etc. Even systems that were designed for novice users or for teaching have not attempted to broadly survey this body of research before making critical decisions about the metaphor or model that the language is based on, the notation that is used in the language, and the environment. For example, the Turing language [Cordy 1992] was designed, in part, as a teaching language for children, with attempts to resolve perceived difficulties with Pascal. However, the list of perceived difficulties is focused primarily on missing features: lack of string handling facilities, type-safe variant records, modularity, concurrency, and type-safe compilation.

The focus of this report is research about the novice programmer. Research that compares novices and experts is included, but research that focuses exclusively on experts is not included here unless it offers general insight into all programmers. Of course, many of the issues mentioned here are applicable to experts as well.

Inspired by the Smith & Mosier user interface guidelines [Smith 1986b], we have gathered and organized this information so that it can be used in the design of new programming systems. The information is organized into topics that span the issues that researchers have explored. While the topics are interrelated in many ways, we have organized them using a subset of the usability principles called *heuristics* defined by the *Heuristic Evaluation* usability engineering method [Nielsen 1994]:[2]

- Visibility of system status.
- Match between system and the real world.
- User control and freedom.
- Consistency and standards.
- Recognition rather than recall.
- Aesthetic and minimalist design.
- Help users recognize, diagnose, and recover from errors.
- Help and documentation.

Each of these heuristics is represented by a section of this document. The introduction to each section contains Nielsen's definition of the heuristic, followed by our interpretation

1. In this report, *system* will be used to mean the programming language as well as the programming environment (set of tools) in which programs are developed.
2. Note that, although this report adopts a subset of the usability *principles* defined in [Nielsen 1994], it does not make use of the usability engineering *method* that is described there.

of the heuristic in the domain of novice programming. Following each introductory section are topics summarizing the novice programming issues that fall into the heuristic.

2. Definitions

Beacon	A common code fragment that serves to indicate the probable presence of a certain high-level operation.
Environment	The collection of tools used in viewing, constructing, running, and debugging programs.
Expressiveness	A measure of the ease in translating a plan into a program. A high-level language is more expressive than assembly language.
Guiding Knowledge	A description of everything a naive user needs to know about the system. This can be the contents of a manual, tutorial, or verbal instructions.
Heuristics	A set of recognized usability principles from [Nielsen 1994].
Inner World	The details of programming that are not directly related to the high level task, such as variable declarations.
Locality	A measure of the proximity of related items, e.g. the declaration and use sites of a variable.
Match-mismatch	A phenomenon where different notations are better depending on the task. Performance is best when the structure of the information sought matches the structure of the notation. Mismatch leads to poor performance.
Metaphor	An real world system that the programmer can use as a reference for how the programming system will work. For example, a stack of dishes is a metaphor for the stack data structure; a variable is often described as a box.
Natural Language	A language that originated in human spoken form, e.g. English.
Notation	The symbols of a programming language and the syntactic rules for combining them into a program.
Plan	A high-level mental strategy for accomplishing a particular programming goal. In order for the plan to be implemented, it must be elaborated and translated into the programming language.

Secondary Notation	Information that is embedded in the program text that is not part of the syntactic structure that is meaningful to the system. For example, comments and indentation are forms of secondary notation in most systems.
Signalling	A secondary notation that uses color and typographic styles to emphasize certain ideas or to clarify the organization of the program. For example, keywords are often shown in boldface or a different color than surrounding text.
Superlativism	An expectation that a particular kind of programming system is superior to another for <u>all</u> programming tasks. Some people expect superlativism of functional languages over imperative languages.
Viscosity	A measure of how much effort is required to make a small change to the program, e.g. how difficult it is to change a conditional into a loop.
Visibility	A measure of how much effort is required to expose desired information.

3. Organization of this Document

Each novice programming usability topic is formatted like this page into a number of parts. The first line contains the item number and title of the issue described. It is followed by a prose description of the issue, definition of terminology, implications or guidelines, and motivations.

Context of Use:	This area indicates where the issue applies, such as notation, metaphor, environment, education, etc.
Justified by:	This area lists how these findings were determined, such as through formal human-factors empirical studies, observation of individual users, or the opinion of experts.
Examples:	This area contains positive and/or negative examples of this issue.
Exceptions:	This area lists exceptions to any guidelines suggested above.
Cross References:	This area lists any other related issues with their section numbers.
References:	This area contains the full list of references for this section; they are also embedded above where appropriate.

4. Visibility of System Status

“The system should always keep users informed about what is going on, through appropriate feedback within reasonable time [Nielsen 1994].”

The research in this section identifies information that is important to the programming process, and suggests ways that the language and the programming environment can help make this information visible, such as by keeping related items close together, by revealing or highlighting important items, by avoiding potentially confusing appearances, and by providing immediate feedback.

4-1. Use Signalling to Highlight Important Information

Typographic signalling is a secondary notation that uses color or typographic styles to emphasize certain ideas or to clarify the organization of the program. Signalling improves comprehension of the signalled material, at the expense of non-signalled material. [Fitter 1979] cites the principles of *redundant recoding* and *relevance* in good notational schemes: in addition to symbolic information there are perceptual cues, thus both perceptual and symbolic characteristics highlight important information; but only information that is actually useful to the user is highlighted.

Many environments automatically signal keywords of the language, even though this may not be the most important information that the reader needs [Baecker 1986]. Instead, the environment should signal semantically important information, or facilitate the signalling of those items that the user feels are important [Gellenbeck 1991a]. Secondary notation should be used to improve access to information that is needed but obscured [Green 1990b]. The user should be informed in advance about the meaning of the signals. Of course, these signals should be correct and not misleading.

Context of Use:	Environment, notation
Justified by:	Empirical studies, expert opinion
Examples:	Many environments highlight syntactic structures of the language, such as keywords. An intelligent environment could use color to highlight semantic information about the program that is less obvious in the syntactic structure, such as the bindings of identifiers. In visual languages, all visible symbols are interpreted by the user as relevant, even if they are incidental [Green 1991]. [Baecker 1986] and [Baecker 1990] describe an elaborate automated system that uses graphic design principles to enhance text in C program printouts, in an attempt to make them more readable, understandable, appealing, memorable and maintainable. This system highlights information that the authors judged to be fundamental, such as: the relationships between comments and the code they discuss; certain tokens such as identifiers; the correct parsing of complex expressions and statements; use of global variables, which are a frequent source of errors; and unusual flow of control. This system improved readability as measured by performance on a comprehension test.
Cross References:	4-2. “Beacons” 4-4. “Beware of Misleading Appearances” 6-3. “Support Secondary Notation”

References: [Baecker 1986, Baecker 1990, Fitter 1979, Gellenbeck 1991a, Green 1990b, Green 1991]

4-2. Beacons

Beacons are common code fragments that serve to indicate the probable presence of certain high-level operations [Brooks 1983]. Although few have been identified, they are typically patterns that are not extremely common, and it is their infrequent appearance that makes them useful in confirming or suggesting a hypothesis about what the code does [Gellenbeck 1991b]. Thus they are useful for high-level understanding, but are less useful for detailed tasks like debugging [Wiedenbeck 1986b]. They have been shown to help experts in program comprehension [Boehm-Davis 1996]. These beacons are so strong that misleading ones can induce false comprehension in experts [Wiedenbeck 1989]. However, there is evidence that novices do not make effective use of beacons, probably because they have not learned the patterns yet [Gellenbeck 1991b, Wiedenbeck 1986a, Wiedenbeck 1986b]. This is supported in an analysis of eye movements of programmers, which found that experts spend more time viewing meaningful areas of the program while novices do not [Crosby 1990]. Even so, using colored cues to mark meaningful sections of code helps experts to find bugs in those sections [Gilmore 1988]. Perhaps the environment should highlight meaningful areas such as beacons with color or other cues, to draw novices' attention to them. This may also be instructional, because the beacons mark schemata that novices must learn anyway [Perkins 1986, Samurçay 1989].

Context of Use: Environment

Justified by: Empirical studies

Examples: A beacon for sorting is the swapping operation, which exchanges the values of two variables:

```
temp := a;
a := b;
b := temp;
```

Cross References: 4-1. “Use Signalling to Highlight Important Information”

References: [Boehm-Davis 1996, Brooks 1983, Crosby 1990, Gellenbeck 1991b, Gilmore 1988, Perkins 1986, Samurçay 1989, Wiedenbeck 1986a, Wiedenbeck 1986b, Wiedenbeck 1989]

4-3. Locality and Hidden Dependencies

Many researchers argue that locality is important in programming: physical proximity should be encouraged and remote references should be avoided [Cordy 1992]; strongly-related subcomponents should be kept together, not dispersed [Bonar 1990]; delocalized plans cause difficulty [Soloway 1988]; and hidden dependencies and poor visibility reduce understanding [Green 1996]. To the extent that information is visible on the screen, working memory limitations are reduced, allowing novices to perform better [Anderson 1985, Green 1987]. These observations are to some extent opposed to modularity and abstraction, which tend to hide details and make related pieces of code more distant from one another [Green 1996]. Part of this problem can be relieved by intelligent use of secondary notation [Green 1990b], or with modern environments that use powerful navigation features to make the remote code easily accessible [Goldenson 1991, Miller 1994].

[Lewis 1987] proposes replacing *programming by synthesis* with *programming by modification*, where a library of examples is provided, from which the programmer chooses an appropriate one for a starting point, identifies needed modifications, then modifies it to suit the current need. This elevates locality because it is an important factor in understanding the examples.

Context of Use:	Environment
Justified by:	Empirical studies, expert opinion

Examples:

The Turing language attempts to group things physically close to one another and avoid remote references where possible. Declarations are not distinct from statements or runtime constants. For example,

```
const temp := x; x := y; y := temp
```

is a valid swap operation at any point in the program, regardless of context or the type of values being swapped [Cordy 1992].

In Turing, control structures implicitly create a scope, encouraging locality [Cordy 1992].

Pascal programmers frequently forget initialization preconditions while coding, requiring them to go back later to insert them [Green 1987]. In contrast, this almost never happens in Prolog, where the preconditions are located adjacent to the focal line. FPL, a graphical language that is equivalent to Pascal, also seems to eliminate this problem, perhaps because the graphical layout prompts the programmer to remember the initialization [Cunniff 1989].

Hypercard seriously reduces the visibility of the program text. It takes too many steps to make a desired item visible [Green 1990a, Green 1996].

Textual languages have hidden dependencies in variables and parameters, as well as in side effects of functions. Visual languages such as LabView and Prograph do well at avoiding hidden dependencies at a local level, but not so well at a global level. Textual languages usually have better visibility than visual languages [Green 1996].

Cross References:	5-5. “Support for Planning” 5-7. “Visual vs. Textual” 5-13. “Modularity and Abstraction” 6-3. “Support Secondary Notation” 8-1. “Minimize Working Memory Load”
References:	[Anderson 1985, Bonar 1990, Cordy 1992, Cunniff 1989, Goldenson 1991, Green 1990a, Green 1990b, Green 1987, Green 1996, Lewis 1987, Miller 1994, Soloway 1988]

4-4. Beware of Misleading Appearances

[Fitter 1979] cites a principle of *restriction* in good notational schemes: the syntax prohibits the creation of code that could easily be confused with other closely-related forms. A typographical error or cognitive slip should result in an invalid program, so that the system can detect the error for the user [Green 1996]. If the error results in a valid but incorrect program, the error will not be detected until it causes the program to behave in a noticeably incorrect manner.

One common mistake among novices and experts is misunderstanding the program because its formatting invites an incorrect interpretation. For example, if objects look alike, kids expect them to behave alike [Smith 1995]. There are two obvious ways to deal with this: 1) the system can impose a formatting that is consistent with the true meaning of the code; or 2) the system can try to interpret the formatting of the code the same way that the user would. The first solution may interfere with allowing secondary notation.

Context of Use:	Notation
Justified by:	Empirical analysis of frequent novice errors
Examples:	Incorrect indentation may lead the user to believe that code is part of a control structure when it is really outside the control structure [du Boulay 1989a]. Stray wires in graphical program cause confusion [Green 1991]. Some students expect that all statements in a program, including those inside procedures, are executed in the order they appear in a program; others think the procedures are executed when they are called *in addition* to executing in a top-to-bottom scan [Sleeman 1988]. Some students think that all statements in the program must be executed at least once, even those that may have been skipped due to branching: that any statements which have not yet been executed are executed before the program terminates [Putnam 1989].
Exceptions:	Early versions of Fortran are notorious for their rigid column-based notation, where restriction was extreme. Some apparently harmless errors in alignment were flagged as errors, while others resulted in unexpected results.
Cross References:	4-1. “Use Signalling to Highlight Important Information” 4-5. “Avoid Subtle Distinctions in Syntax” 6-3. “Support Secondary Notation”
References:	[du Boulay 1989a, Fitter 1979, Green 1996, Green 1991, Putnam 1989, Sleeman 1988, Smith 1995]

4-5. Avoid Subtle Distinctions in Syntax

Notation should avoid subtle distinctions in syntax which might be overlooked or confused by novices. As described above (see “Beware of Misleading Appearances” on page 245), the principle of *restriction* advises against the use of syntax that is so similar to other forms that it is easily confused [Fitter 1979]. Novices get confused when there are two different syntaxes to accomplish the same effect [Eisenberg 1987]. More planning is required when there are many different legal solutions to a goal, which leads to frequent code changes [Gray 1987].

Context of Use: Notation

Justified by: Empirical studies, observation of individual users

Examples: The difference between the quoted string “123” and the numeric value 123 is a problem [du Boulay 1989a].

Novices have difficulty because Pascal does not permit a comma to be used as punctuation in a number. For example: 32,000 is illegal while 32000 is legal [Pane 1996].

A common problem in C is the distinction between the assignment operator `=`, and the equality operator `==`. For example, sometimes the programmer will writes `if (a = 0)` instead of `if (a == 0)`, which results in an assignment where comparison was desired. Pascal has a similar distinction between `:=` for assignment and `=` for equality, but this is not so serious due to restriction: syntax prohibits one of them to be used where the other is legal. Some systems use a special symbol for assignment to avoid the confusion with equality [Baecker 1986]. As mentioned in “Beware of Misleading Appearances” on page 245, a typographical error or cognitive slip should result in an invalid program, so that the system will detect the error for the user [Green 1996].

In C, indexing of arrays is done with square brackets, but initialization is done with curly braces:

```
int a[] = {1,2,3};
```

In C, it is very easy to accidentally comment out a large block of code. It is not an error to have a missing close-comment delimiter. Instead, the comment continues to the next occurrence of the close-comment delimiter. Modern environments use color signalling to make this error visible.

Cross References: 4-4. “Beware of Misleading Appearances”
5-3. “Consistency with External Knowledge”
5-14. “Cognitive Issues”

References: [Baecker 1986, du Boulay 1989a, Eisenberg 1987, Fitter 1979, Gray 1987, Green 1996, Pane 1996]

4-6. Support Incremental Running and Testing with Immediate Feedback

Immediate feedback aids problem solving [Lewis 1987]. The ability to test partial solutions is an important feature for novices and experts alike. Running the program should be encouraged because it is a useful debugging strategy [Gugerty 1986b]. When novices adopt a practice of testing their code incrementally, they perform better [Goldenson 1991, Green 1996, Perkins 1986]. This has a bigger impact on performance than good error messages in a batch-compiled delayed-feedback environment [Davis 1993]. These observations can be interpreted as a call for lisp-like dynamic languages [Smith 1992], but in fact the environment can provide this feature in traditional compiled languages such as Pascal [Goldenson 1991].

The computational machine should reveal its internal workings, and should do it in terms of the language itself [du Boulay 1989b]. A powerful graphical debugger will be used by novices not only for debugging, but also as an aid to program comprehension even in the absence of bugs [Goldenson 1991]. However, novices must be trained to use these tools effectively [Miller 1994]. [Brusilovsky 1997] points out that an important feature of mini-languages for novices is that they be capable of operating in *dialog* mode, where individual commands can be issued by the user and are executed immediately with visible feedback. [Clements 1995] lists this as a design principle for novice programming environments.

In traditional compiled languages, beginners are also confused by the need to recompile after making a change, and the need for their program to be complete before it can be run [du Boulay 1989a]. The Geo-Logo environment addresses this problem by updating the program's output as soon as code is changed [Clements 1995].

Context of Use:	Environment, programming paradigm
Justified by:	Empirical studies
Examples:	Spreadsheets provide immediate feedback, in contrast to other environments where the programmer must recompile, re-execute, and re-enter data in order to test a change. This is an important factor in the success of spreadsheets [Lewis 1987, Nardi 1993]. A powerful graphical debugger such as the one in the MacGnome environments shows live graphical views of the data structures which are continuously updated while the program is running. The debugger attempts to display the data in a semantically meaningful way, such as displaying records, linked lists, binary trees, and multidimensional arrays in the same way they are pictured in textbooks and in the classroom. Recursive procedure calls are also easier to understand because the call stack graphically represented in the debugger. These displays facilitate understanding of the data structures and the program that manipulates them [Miller 1994, Myers 1988].

Cross References:	5-12. “Choosing a Paradigm” 10-1. “Support for Testing and Debugging”
References:	[Brusilovsky 1997, Clements 1995, Davis 1993, du Boulay 1989a, du Boulay 1989b, Goldenson 1991, Green 1996, Gugerty 1986b, Lewis 1987, Miller 1994, Myers 1988, Nardi 1993, Perkins 1986, Smith 1992]

5. Match Between System and the Real World

“The system should speak the user’s language, with words, phrases, and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order [Nielsen 1994].”

The research in this section investigates the expectations and behaviors that a novice brings to programming, such as natural language and knowledge of the real world. It discusses ways that the programming system can effectively exploit the expectations and support the behaviors, in order to maximize the net positive transfer to programming. Several points are made about common programming constructs that do not match well with the way users tend to express concepts in natural language. In addition, the task-dependent nature of the effectiveness of the programming system is examined. While this section covers consistency between the programming system and the outside world, “Consistency and Standards” on page 286 covers internal consistency. [Payne 1986] describes a formal method for assessing both of these forms of consistency.

5-1. Choose an Appropriate Metaphor

A metaphor is a familiar analogy for how the programming system works. When the metaphor is good, users can infer how the programming system works by referring to their existing knowledge and expectations about how the modeled system works; otherwise they might be required to learn a collection of rules that seem arbitrary. In order to maximize this transfer of knowledge, the metaphor should be based on, and conceptually close to, a concrete real-world system that is widely known by the user audience [Smith 1994]. This familiarity requirement is violated by Prolog, where misconceptions abound in users' models of searching, matching, and backtracking [Fung 1990, Fung 1987, Mendelsohn 1990]. An appropriate concrete model can have a strong positive effect on the usability of a programming language [Mayer 1989].

Context of Use:	Computational metaphor of the language
Justified by:	Empirical studies, expert opinion
Examples:	Traditional programming languages use a computational model of the von Neumann machine, which has no physical world counterpart. Learning this computational model is an important stumbling block for novices [du Boulay 1989a, du Boulay 1989b]. The spreadsheet is widely viewed as a successful instance of a programming language that is useful to non-programmers. An important advantage of the spreadsheet is that it is based on a metaphor that fits very well with the tasks of its audience: page-oriented numerical computation for financial or other purposes [Nardi 1993]. Use of spreadsheets requires mastery of only two concepts: cells as variables and functions as relations between variables. Typically users use fewer than ten functions, including basic arithmetic and rounding. It is not necessary to string together low-level primitives, allocate memory, name variables, include files, etc. It is a familiar, concrete, visible representation that allows users to feel as though they are working directly on the task [Lewis 1987]. Unfortunately, this metaphor does not seem to extend well to general-purpose computation. Logo uses the metaphor of a turtle in a two-dimensional world. Even this concrete model has its difficulties. For example, when the turtle is facing south, the user's left is the turtle's right, and vice versa [Mendelsohn 1990]. [Resnick 1994] describes the extension of the Logo metaphor to parallel computing. Boxer uses a two-dimensional spatial metaphor for the organization of programs, but is not constrained to a single-level hierarchy of cells as spreadsheets are. All computational objects are represented in terms of a hierarchy of boxes, which can contain data such as text or graphics, or can contain behaviors in the form of Logo-like pro-

grams. It uses the metaphor of a port for accessing the contents of a box from a distant place in space [diSessa 1989].

[Brusilovsky 1997] surveys a collection of mini-languages for novices that are based on the metaphor of a robot, and claims that they are intrisically engaging and visually appealing. One such language that achieved widespread usage is Karel the Robot [Pattis 1995].

[Finzer 1993] describes “Programming by Rehearsal”, where the programming process consists of moving “performers” around on “stages” and teaching them how to interact by sending “cues” to one another.

Pursuit is a visual shell that uses a comic-strip metaphor to represent programs [Modugno 1996].

Exceptions: Several systems are cited by [Mendelsohn 1990] as moving from the abstract toward the concrete: ARK [Smith 1986a]; Boxer [diSessa 1989]; ThingLab [Borning 1985]. He concludes that in these concrete systems, semantic complexities are not banished, users can not see the plans, and the systems have poor visibility and viscosity.

Cross References: 5-2. “Consistency with Metaphor”
5-11. “Support Direct Manipulation and Definition by Example”

References: [Borning 1985, Brusilovsky 1997, diSessa 1989, du Boulay 1989a, du Boulay 1989b, Finzer 1993, Fung 1990, Fung 1987, Lewis 1987, Mayer 1989, Mendelsohn 1990, Modugno 1996, Nardi 1993, Pattis 1995, Resnick 1994, Smith 1994, Smith 1986a]

5-2. Consistency with Metaphor

The language should be consistent with its metaphorical model. It should abide by any suggestions that can be derived from the metaphor. [Halasz 1982] lists three classic problems with metaphors: the target domain has features not in the source domain, the source domain has features not in the target domain, and some features exist in both domains but work very differently. Novices frequently encounter difficulty with the limits of the metaphor or analogy: mistakes arise out of attempting to extract too much from it.

Context of Use:	Metaphor and notation
Justified by:	Empirical analysis of frequent novice errors
Examples:	Novices expect the computer to understand the meaning of a variable based on its name. For example, students expect the read statement to select values based on the names of the variables. With `READLN(odd, even)` and the input “2 3”, they expect the computer to read 3 into `odd` and 2 into `even` [Putnam 1989, Sleeman 1988]. When a variable is described as a box or a slate, users assume that it can hold more than one value at a time like the real-world counterparts. For example, students will expect a read statement to accept multiple values into the variables being read into. In `READLN(odd, even)` with the input “2 3 5 10”, students expect the computer to read 3 and 5 into `odd` and 2 and 10 into `even`. When they encounter these multiple-value variables in a subsequent conditional statement, students variously think that: • only the first value is used, • the comparison cannot be made, or • the program implicitly loops until the values in the variables have been consumed [Putnam 1989, Sleeman 1988]. When a variable is described as a box, users sometimes think that a sequence such as `a=2` followed by `b=a` means that `a` no longer holds the value `2`. When computers are anthropomorphized, novices tend to expect computers to be non-rigid like humans, and thus are not precise in describing a task [du Boulay 1989a]. When a program is described as a recipe, novices expect that it is ok to leave out certain details, the way “remove egg from its shell” is left out of most recipes that use eggs [du Boulay 1989a].
Cross References:	5-1. “Choose an Appropriate Metaphor” 5-3. “Consistency with External Knowledge”
References:	[du Boulay 1989a, Halasz 1982, Putnam 1989, Sleeman 1988]

5-3. Consistency with External Knowledge

Users bring to the programming task external knowledge that might interfere with correct understanding of the language. Most beginner programming errors can be interpreted as incorrect transfers from other representation/processing systems to the computer device [Bonar 1989, Mayer 1987]. Where their knowledge is lacking, it is common for novices to guess incorrect language syntax or semantics; these errors are indicators of transfers from other knowledge domains that are not compatible with the programming language [Hoc 1990].

Languages often use keywords that are loaded with meaning from natural language, and notation that is like math. While the mnemonic value of keywords is useful, it is important to beware of what is called the *human interpreter problem*, where reading the program in a natural language manner leads to an interpretation that is inconsistent with the correct meaning of the program [Bonar 1988b, Spohrer 1989a, Spohrer 1986b, Taylor 1990]. Students attribute to the machine the reasoning power of an average human [Sleeman 1988]. A large portion of bugs arise from inconsistency within the programming language or inconsistency between the programming language and the user's outside knowledge of the world or natural language. [Pea 1986] discusses language-independent conceptual bugs which affect the ways in which novices perceive the computing domain.

Context of Use: Notation, metaphor

Justified by: Empirical studies, analysis of frequent novice errors, expert opinion

Examples: There is a litany of inconsistencies between mathematical knowledge and the use of similar notation in programming languages like Basic, Pascal and C. Some examples lie in the use of variables [du Boulay 1989a, Putnam 1989]:
• `a=2` and `2=a` are not symmetric in assignment as they are in math;
• math does not use the concept of previous and next values of a variable, such as in the assignment statement `a=a+1`;
• math treats the identity of two symbols as permanent for the duration of the problem, while it is transient in programming, such as in the assignment statement `a=b`;
• math offers no hint about the direction of assignment – whether the value of `b` goes into `a` or vice versa – in the assignment statement `a=b`;
• initialization of variables is a concept that is foreign to math or counting.

In math, the symbol "+" can be used as a summation operator with an arbitrary number of arguments. In many programming languages, "+" is only a binary operator [Hoc 1990]. Notably, spreadsheets do not restrict the addition to be a binary operator [Lewis 1987].

As mentioned in "Avoid Subtle Distinctions in Syntax" on page 246, Pascal does not permit a comma to be used as punctuation in a number [Pane 1996].

In natural language, `then` and `and` are often used in the sense of "what next", unlike their use in Pascal or C: "I went to the shop and then I bought a paper"; "wash your hands and set the table" [Bonar 1989, du Boulay 1989a].

In Pascal, `Repeat` is used before the item(s) being repeated, but in natural language the opposite is usually true [Bonar 1988b, du Boulay 1989a].

In Logo, `STOP` causes the flow of control to return from the current procedure to the caller, but kids misinterpret this to mean that execution is halted completely [Kurland 1989].

One example of how programming does not support the natural way of expressing a task is sorting. When users are asked to sort a series of real boxes, inserting a box pushes the other boxes to make room. When dealing with arrays, this operation must be carried out explicitly by the programmer [Hoc 1990].

[Spohrer 1986b] found that many novice bugs occur when the user generates code in an order that is different than the built-in operator precedence in the language. The user expects that the program will execute in the order of generation, rather than according to the operator precedence rules of the language. This suggests that all operator precedence should be explicit rather than implicit. For example, expressions could be automatically parenthesized to show their evaluation order.

Cross References:	4-5. "Avoid Subtle Distinctions in Syntax" 5-1. "Choose an Appropriate Metaphor" 5-2. "Consistency with Metaphor" 5-6. "Naturalness of the Programming Language"
References:	[Bonar 1989, Bonar 1988b, du Boulay 1989a, Hoc 1990, Kurland 1989, Lewis 1987, Mayer 1987, Pane 1996, Pea 1986, Putnam 1989, Sleeman 1988, Spohrer 1989a, Spohrer 1986b, Taylor 1990]

5-4. Closeness of Mapping

[Hoc 1990] describes programming as adaption of a plan from a familiar strategy to one that is compatible with the computer. This adaption is a refinement process that can lead to the detection of incompatibilities between the real-world plan and the computer's capabilities, or to a program solution that is not optimal. Similarly, [Green 1996] describes programming as mapping of operations in the problem domain into corresponding operations in the program domain. Thus it should be helpful to have a closeness of mapping between the task domain and program entities. [Merrill 1993] proposes as a design principle for all learning environments that the translation process from the student's internal plans to the solution's external representation be minimized. The extent to which the language facilitates this is called the *expressiveness* of the language [Bell 1991].

Users have difficulty understanding low-level primitives and how to compose them to form high-level components of a plan [Hoc 1990, Nardi 1993]. This is one of the great cognitive barriers to programming [Lewis 1987]. From a psychological point of view, the composition of these primitives into high-level operations is difficult for the following reasons [Lewis 1987]:

- synthesis is inherently hard, because a large number of possible combinations must be explored;
- since primitives are unrelated to the task, they are difficult to understand;
- for the same reason it is hard to see what combination of primitives will produce the correct task-related behavior;
- synthesis must be carried out with little immediate feedback; when feedback becomes available it is informative only about the behavior of the big assembly rather than about the many little choices that had to be made in putting it together;
- since the fundamental maneuver is replacement of "what is wanted" by "what to do", information about intent is not expressed directly and must be maintained separately, mentally or physically; and,
- it requires plan merging: constructions must be formed that carry out multiple purposes simultaneously.

In addition, in traditional programming languages [Lewis 1987]:

- synthesis results in high viscosity because primitives and rules of combination are complex;
- commonly used primitives enforce the inner world / outer world distinction in which data manipulable by the system cannot be manipulated by the user;
- reliance on sequence as the fundamental mode of combination of primitives requires users to specify much irrelevant information; and,
- it takes great care and discipline to make sure the code is comprehensible.

Instead, users should be permitted to formulate the problem using the objects, relationships, and processes of the problem domain [Lewis 1987]. [Fitter 1979] cites a principle of *revelation* in good notational schemes: the notation perceptually mimics the solution structure.

Educators often address these problems by choosing to begin teaching with a small subset of the language, and to incrementally expand the subset until the entire language is finally exposed [Brusilovsky 1994]. Sometimes, special programming environments are built around a starting subset of the full language. Another approach is to invent a special mini-language for teaching which is not a proper subset of any full language. Usually these provide only the minimal set of primitives that are necessary to embody the desired programming concepts, and make all operations visible as concrete actions on the screen. [Brusilovsky 1997] surveys a collection of mini-languages that are used as an introduction to programming (e.g. Karel the Robot [Pattis 1995]).

A related requirement is to have built-in types and abstractions that are appropriate for the domain [Cordy 1992]. [Nardi 1993] points out that successful end-user systems are task-specific and empower the user. They lack the power of general purpose programming languages, but also lack the steep learning curve. This suggests the creation of a task-specific programming language for every task domain, which is incompatible with the desire to make a general-purpose language and environment. One approach to this dilemma is to provide high-level, task-specific, user-extensible libraries for the desired domains, and to try to eliminate the need for novices to learn a lot of low-level primitives [Green 1996, Green 1991, Guzdial 1992, Mendelsohn 1990].

Context of Use:	Notation and environment
Justified by:	Observation of individual users.
Examples:	Here are two examples of the refinement that is required to adapt a familiar strategy or plan to a programming solution: • Making room in an array for insertion. The programmer must satisfy preconditions that do not exist in the original situation. • using “+” as a binary operator, with initialization of an accumulator variable, instead of simply requesting summation. The user must decompose elementary actions into even more elementary ones [Hoc 1990, Lewis 1987]. The spreadsheet has a close mapping to the domain of numerical tables in accounting, and the common operations that are performed in that domain. There is a great distance in mapping the built-in operations of a language like Pascal to tasks such as manipulating strings. [Green 1996] uses cognitive dimensions to identify the following examples of closeness of mapping: • poor: adding a vector in C or Basic; looping in LabView; success/failure in Prograph. • good: electronics instrumentation in LabView; persistent variables in Prograph; locality of program plans in Prograph and LabView. [Nardi 1993] claims that Hypercard’s language, HyperTalk, is too much like a conventional programming language and not close enough to the end-user’s needs.

High-level languages are more expressive than assembly languages. For example, it takes fewer statements to implement a loop in a high-level language.

Exceptions: Even with high-level task-specific components, there is evidence that novices have difficulty assembling them into programs [Spohrer 1989a].

Cross References:
4-1. “Use Signalling to Highlight Important Information”
4-6. “Support Incremental Running and Testing with Immediate Feedback”
5-1. “Choose an Appropriate Metaphor”
5-3. “Consistency with External Knowledge”
5-14. “Cognitive Issues”
6-2. “Viscosity”
9-1. “Principle of Conciseness”

References: [Bell 1991, Brusilovsky 1997, Brusilovsky 1994, Cordy 1992, Fitter 1979, Green 1996, Green 1991, Guzdial 1992, Hoc 1990, Lewis 1987, Mendelsohn 1990, Merrill 1993, Nardi 1993, Pattis 1995, Spohrer 1989a]

5-5. Support for Planning

Some researchers describe expert programming as an opportunistic activity [Green 1990b, Green 1996]. However, [Ball 1995] claims that experts actually are using sophisticated strategies to schedule and prioritize their activities. [Soloway 1984] and [Rist 1995] describe programming as the composition of plans or schemas. Plan usage is pervasive among novice programmers, and when they lack an appropriate plan they use pre-programming knowledge to fabricate one which may be buggy [Bonar 1989]. An additional source of many novice bugs is difficulty with plan composition, where the programmer is unable to anticipate all of the interdependencies when combining programming plans [Spohrer 1986a, Spohrer 1989a, Spohrer 1989b, Spohrer 1986b]. This interleaving of plans should be minimized [Green 1987].

The programming environment should allow programmers to work directly in plan terms [Mendelsohn 1990, Parker 1987]. Many aspects of program planning are difficult for novices: they do not know how to choose key components, they are stumped by a blank screen, and they need a process to guide their programming. An environment that assists in this planning process yielded improvements in novice program generation [Guzdial 1992]. Universe [Parker 1987], TEd [Ormerod 1996], and Bridge [Bonar 1987, Bonar 1990, Bonar 1988a] are similar systems. Bridge provides an intermediate representation for plans that avoids dispersing them: icons that fit together like jigsaw puzzles, with smaller icons for values and constants. [Corbett 1995] describes a tutoring environment where students are required to explicitly state subgoals, which most environments leave implicit. An empirical study showed that students reached mastery more quickly in this environment. Similarly, the GIL Lisp tutoring environment encourages users to make explicit explanations and predictions of ordinarily implicit behaviors and states, allows access to internal states that would otherwise be invisible, and has an on-screen representation of the structure of partial solutions to help students track their solution process [Merrill 1993, Merrill 1992, Reiser 1992]. These features lead to superior performance in both textual and diagrammatic programming environments [Merrill 1994].

Developing a suite of idioms, or plans, for solving small-scale goals are one of the important difficulties for novice programmers [du Boulay 1989a]. Selection of an appropriate plan from the suite is difficult [Scholtz 1993]. These skills should be taught explicitly [Perkins 1989], and required parts of a plan should be prompted by the syntax (e.g. initialization) [Green 1987].

The Prolog community introduced the concept of programming *techniques*, which are a small set of meta-plans that are language-dependent but domain-independent [Brna 1991]. [Bowles 1994] and [Ormerod 1996] describe systems that use techniques as a framework to support program editing, analyzing novice errors, in tracing and debugging, and in teaching programming skills.

Context of Use:	Environment
Justified by:	Empirical studies, expert opinion

Cross References:	5-3. “Consistency with External Knowledge” 5-4. “Closeness of Mapping”
References:	[Ball 1995, Bonar 1987, Bonar 1990, Bonar 1989, Bonar 1988a, Bowles 1994, Brna 1991, Corbett 1995, du Boulay 1989a, Green 1990b, Green 1987, Green 1996, Guzdial 1992, Mendelsohn 1990, Merrill 1993, Merrill 1994, Merrill 1992, Ormerod 1996, Parker 1987, Perkins 1989, Reiser 1992, Rist 1995, Scholtz 1993, Soloway 1984, Spohrer 1986a, Spohrer 1989a, Spohrer 1989b, Spohrer 1986b]

5-6. Naturalness of the Programming Language

[Ledgard 1980] observed that natural language is better than a notational editing language for text editing, but [Curtis 1988] found that a textual pseudocode and graphical flowcharts were both better than natural language in program comprehension. When novices get stuck in their programming task, they rely on natural-language plans that they acquired before exposure to programming [Bonar 1989]. When the natural language plan is not compatible with the programming language, a bug will result. Several studies have found that when non-programmers are asked to write step-by-step informal natural language procedures, many different people use the same phrases to indicate looping structures and other standard programming tasks [Biermann 1983, Bonar 1986, Miller 1981]. Furthermore, students confuse phrases in natural language with the English keywords of a language like Pascal, and thus write their code as if it has the semantics of natural language [Bonar 1988b].

[Miller 1981] finds that nonprogrammers omit many actions from natural language problem solutions, thus relying on a human-like interpreter to fill in the missing details. For example, they use fewer control structures in written instructions than are required in actual program solutions. However, [Galotti 1985] was able to elicit nonprogrammers to use more control instructions by describing the instructee as a naive alien. One possible explanation is that novices use rules of cooperative conversation (see [Grice 1975]), expecting the computer to possess a modicum of common sense, and thus don't state the obvious. However, even when control structures are present, [Galotti 1985] found that instructions about iteration, or about what to do if a test condition is not met, are often vague or unspecified.

[Nardi 1993] points out serious problems with attempts to model programming languages after natural languages: the computer and programmer do not have the shared context that is present in human-human conversation, and it is not obvious where the limits of the computer’s understanding are. Indeed there will be such limits as long as artificial intelligence has not been achieved.

However, novices are capable of learning and using programming languages that are not based on natural language, as long as they are task-specific and high-level [Nardi 1993]. Even these should support the ways that people naturally express problem solutions [Hoc 1983, Miller 1981]. When given a choice of programming methods to accomplish a task (e.g. sorting), novices tend to use the method they would use by hand, even if it is more complicated than another method [Hoc 1990, Nyuyen-Xuan 1987].

Context of Use:	Notation
Justified by:	Empirical studies and observations of individual users
Examples:	Many novice bugs are caused by a confusion of the correct choice of `AND` or `OR` in combining boolean tests. An example of this problem is when the programmer is checking for valid input from a menu of choices. Often novices will code `if (ch <> 'a') OR (ch <> 'b') OR (ch <> 'c')`, when the correct logical connector is

AND. This problem appears to result from users' lack of an operational understanding of DeMorgan's Laws of logical identity, which describe the way the negation interacts with AND and OR in propositions. Since the english language treats this situation informally ("if the choice is not a, b, or c"), the confusion is not unexpected [Spohrer 1986a, Spohrer 1986b].

One way to avoid the above problem in Pascal is to use a set, where `if (ch <> 'a') AND (ch <> 'b') AND (ch <> 'c')` becomes `if` **`NOT`** `(`**`ch IN`** `['a', 'b', 'c']).` But there are two things to note about this syntax. First, the most natural way to express this in English ("if the **character** is **not in** the set...") leads novices to misplace the NOT, coding the expression illegally as `if (`**`ch NOT IN`** `['a', 'b', 'c']).` Second, even when the NOT is positioned correctly in the expression, parenthesis are required for it to be evaluated correctly; such issues of operator precedence rarely surface in natural language.

Another confusion is that programming languages often use OR for inclusive-or, while natural languages use the word for exclusive-or.

Cross References: 5-3. "Consistency with External Knowledge"
5-4. "Closeness of Mapping"
5-5. "Support for Planning"

References: [Biermann 1983, Bonar 1986, Bonar 1989, Bonar 1988b, Curtis 1988, Galotti 1985, Grice 1975, Hoc 1983, Hoc 1990, Ledgard 1980, Miller 1981, Nardi 1993, Nyuyen-Xuan 1987, Spohrer 1986a, Spohrer 1986b]

5-7. Visual vs. Textual

[Myers 1990] presents a taxonomy of visual programming languages. There is a widespread tendency to expect visual languages to be superior to text for novice programming. [Green 1991] calls this graphical superlativism, and cites the following claims in favor of visual languages over textual languages: two-dimensional visual perception is more natural and efficient than reading text; it is easier to get an overview of program structure in visual systems; it is easier to read a visual program because purely syntactic devices are reduced; the number of variable names is reduced in visual programs; in visual systems, relationships between components are expressed by lines rather than symbols, making it easier to follow the routes; iconic representation of components may be easier to discriminate and recognize than textual names and symbolically-expressed relationships; extra information is conveyed by the spatial layout of the visual program (secondary notation). [Blackwell 1996] is a comprehensive survey of these claims from the visual programming literature. If the claims are true, the benefits may be particularly strong for novices. In a comparison of text-based and visual rapid-prototyping tools on a simple programming task, novice performance was closer to that of experts with the visual tools [Hasan 1996]. In Pursuit, a visual language based on a comic-strip metaphor was shown to be more effective than an equivalent textual language for novice generation of shell script programs [Modugno 1996].

Graphical superlativism was supported in [Cunniff 1987], where novices were able to recognize certain simple structures and to hand-execute short program segments more quickly and more accurately in a graphical language than in an equivalent textual language. However, there is a considerable amount of research indicating that graphical superlativism does not hold in larger more complex programs or for “deprogramming” tasks, where the novice must derive high-level goals and plans from the program text in order to fully understand and extend the program.

Diagrammatic notations are good only for certain purposes [Gilmore 1984]. [Green 1991] claims that formalisms based on control flow are linear with exceptions, so they are easily represented in a textual language; while formalisms based on data flow may be more appropriately represented in a visual language. However, [Curtis 1988] found that a flowchart representation was superior to textual pseudocode when the task involved tracing flow of control, but not for discerning high-level relationships. If there is any advantage of flowcharts over text it is at the detailed level, rather than at the overview level [Green 1992]. This may be because flowcharts are poor for modularity [Green 1990a]. There is little advantage in using flowcharts for supplementary documentation, although they are useful when they display knowledge that is difficult to extract from the program text [Shneiderman 1986, Shneiderman 1977]. [Atwood 1978] found that a textual program design language was better than a flowchart. Overall, graphical programs take longer to understand than textual ones [Green 1992, Green 1991]. [Moher 1993] compared program comprehension in graphical vs. textual representations and found that graphics were no better than text and sometimes considerably worse.

Flowcharts are of little help in debugging. They help to trace execution flow and localize the area where the bug is located, but are insufficient to identify the actual bug [Brooke

1980a, Brooke 1980b].

Visual languages are not more natural than text [Nardi 1993]. Most visual languages have high viscosity – they require a lot of effort in layout rearrangement when making changes; and they impose an extra burden on the user to guess ahead so that they format the program nicely and avoid future rearrangement [Green 1996]. Another problem with visual languages is their inefficient use of screen space [Nardi 1993].

[Nardi 1993] points out that spreadsheets are based on a textual language, and yet are very successful. However, spreadsheet programmers make use of visual imagery in planning manipulations, implying that mental images of program layout are an important resource [Saariluoma 1994].

Context of Use: Notation, environment

Justified by: Empirical studies, observations of individual users, expert opinion

Examples: KidSim is a programming environment that attempts to be completely visual [Smith 1994]. It allows the user to construct “simulations” of agents in a two-dimensional grid. This was motivated by results in an earlier system named Playground [Fenton 1989], where children had great difficulty with a scripting language, even though a structure editor was provided to assist with syntactic correctness. However, in empirical tests of KidSim, the authors found that text was helpful in some situations. For example, adding the text “and if” at the beginning of each conditional expression made rules easier to understand [Cypher 1995]. While KidSim’s mostly-visual approach appears to be productive in this limited domain, it is not at all clear that a useful general purpose programming environment could be completely visual.

In visual languages, the graphics must be well-designed and recognizable [Green 1991].

Flow of data is very difficult to perceive in standard textual languages, but data flow languages make this information easily accessible [Green 1990a].

Cross References: 5-8. “Effectiveness of Notation is Task Dependent”
6-1. “Avoid Requiring Premature Commitment”
6-2. “Viscosity”
6-3. “Support Secondary Notation”

References: [Atwood 1978, Blackwell 1996, Brooke 1980a, Brooke 1980b, Cunniff 1987, Curtis 1988, Cypher 1995, Fenton 1989, Gilmore 1984, Green 1990a, Green 1992, Green 1996, Green 1991, Hasan

1996, Modugno 1996, Moher 1993, Myers 1990, Nardi 1993, Saariluoma 1994, Shneiderman 1986, Shneiderman 1977, Smith 1994]

5-8. Effectiveness of Notation is Task Dependent

[Green 1992] describes the *match-mismatch* phenomenon, where different notations are better depending on the task. Performance is best when the structure of information sought matches the structure of the notation, and mismatch leads to poor performance. There are several examples of this in "Visual vs. Textual" on page 262. However, this effect may be diminished by other factors such as prior experience and the programmer's dominant mental representation of the program [Good 1996]. While these analyses are based on program understanding, rather than program generation, there is a substantial amount of parsing and understanding during the coding process. For example, [Green 1987] proposes a model of programming where, due to working memory limitations, the programmer forgets some parts of the program that are already written, and is forced to *parse* them in order to recover their details. That research found that the parsing problem is more severe in Basic and Prolog than in Pascal. The task-dependent effectiveness of notation suggests that a programming environment that supports multiple (e.g. visual and textual) representations of the program might be a fruitful endeavor.

Context of Use:	Notation, environment
Justified by:	Empirical studies
Examples:	Traditional structured languages with nested conditionals support forward analysis of *sequence* information, e.g. "given these inputs, what is the result". Declarative languages support backward analysis of *circumstantial* information, e.g. "given this output, what must the inputs have been" [Green 1992]. Features that facilitate the parsing task may work contrary to the code generation task. For example, the features that make Pascal easier to parse into plan structures may be the very features that inhibit linear generation of code. In many other notations it seems easier to develop code than to recover its meaning [Green 1990b].
Examples:	5-4. "Closeness of Mapping" 5-5. "Support for Planning" 5-7. "Visual vs. Textual" 8-1. "Minimize Working Memory Load"
References:	[Good 1996, Green 1990b, Green 1987, Green 1992]

5-9. Control Structures

One area difference between spreadsheets and many other programming languages is control structures. The lack of control structures in spreadsheets is an advantage [Nardi 1993]. [Lewis 1987] also points this out, and claims that spreadsheets are the model of the future because they allow the learner to suppress the *inner world* of programming, the world of variable declarations, loops, and I/O. Relationships among variables can be set up declaratively, and the system will maintain consistency. [Wandke 1988] cites a dramatic increase in cognitive effort when using control structures, leading to a reluctance to define macros for repetitive tasks even if it would dramatically reduce the number of keystrokes required to perform a task.

[Rogalski 1990] found that:

- high-level control structures are more difficult to express than the “goto” or “jump” style of control, but the latter is more difficult for managing complex control flow correctly;
- control structures that use positive alternatives present fewer difficulties than negative ones (e.g. `repeat until X` is easier to understand than `while not X`, especially if `X` is a compound expression);
- difficulty increases with depth of nesting; and
- students with a better background in math learn new control structures faster.

[Sime 1977a] and [Sime 1977b] confirm that high-level control structures help the novice to manage flow of control, and also found that a structure editor assisted novices in generating correct nested control structures.

Many novice errors with control structures can actually be attributed to misconception of variables. Describing a variable as a name or an address is the first step toward fixing this, although a more complex model is required when variables occur in iterative or recursive programs in imperative languages: the variable is no longer an address with a value, but needs to be seen as a function of execution, or a sequence of values [Samurçay 1989].

Indeed, most introductory programming textbooks focus a great deal of attention on the use and understanding of control structures, suggesting that details about how control structures work is an area of great difficulty for novices. However, in a study of high-frequency bugs, [Spohrer 1986a, Spohrer 1989a, Spohrer 1986b] found that only about one-third of bugs arise from novice misunderstandings of control structures. [Arblaster 1979] found that any type of structure is better than no structure at all, and that hierarchical structuring is not better than other types of structuring.

Context of Use:	Notation
Justified by:	Empirical studies, observations of individual users
Examples:	With IF statements, students make the following errors [Putnam 1989, Sleeman 1988]: • expect the program to halt with an error if the condition on the IF statement is false and there is no ELSE clause; • expect both the THEN and ELSE clauses to be executed;

	• expect the THEN clause to execute whether or not the condition is true; • treat a statement after an ELSE-less IF statement as though it is the ELSE clause.
Exceptions:	Prolog is an attempt at suppressing the inner world of programming, and is notoriously difficult for novices.
Cross References:	5-3. “Consistency with External Knowledge” 5-4. “Closeness of Mapping” 5-6. “Naturalness of the Programming Language” 5-10. “Loop and Recursion Control Structures”
References:	[Arblaster 1979, Lewis 1987, Nardi 1993, Putnam 1989, Rogalski 1990, Samurçay 1989, Sime 1977a, Sime 1977b, Sleeman 1988, Spohrer 1986a, Spohrer 1989a, Spohrer 1986b, Wandke 1988]

5-10. Loop and Recursion Control Structures

A common area of difficulty for novices is looping. Part of this can be attributed to an inability to generalize, which is evidenced by a tendency for novices to make a list of repeated instructions instead of coding a loop [Hoc 1989, Onorato 1986], or to an inability to develop an adequate mental model of the looping structure [Kessler 1989, Pirolli 1985]. Sometimes the bugs in novices' mental models are subtle and difficult to detect [Kahney 1989]. However, a large part of the difficulty of loops may be overcome by designing the looping control structure(s) carefully.

Pascal provides a `while` loop, where the looping condition is checked at the top of the loop (top-exit); and a `repeat` loop, where the looping condition is checked at the bottom (bottom-exit). Other possibilities are: a loop that can exit from a check in the middle of the loop (middle-exit); or a loop that exits from anywhere as soon as the condition fails (daemon-exit). In describing a plan, novices use a bottom-exit strategy when it seems easier, but then revert to a middle-exit strategy for all other situations [Wu 1991]. [Rogalski 1990] reinforces this with the finding that the top-exit strategy is more difficult than the bottom-exit strategy, hypothesizing that novices have difficulty representing and expressing a condition about an object that they have not yet operated on. Pascal does not provide a middle-exit loop control structure, so novices are forced to adapt their middle-exit plan to a while or repeat loop when they write the code; causing performance to suffer. [Soloway 1989] found that providing a middle-exit control structure would increase accuracy and would not interfere with program readability.

Construction and expression of the loop invariant is an important component of an iterative plan. But, in spontaneous verbal plans novices tend to base their models of loops on representing a succession of actions, rather than on representing the invariant relationships among variables. Even when asked explicitly, novices have difficulty specifying a loop invariant. Also, novices tend to use different names at each step of the iteration to label the same functional variable, and they do not spontaneously elaborate an exit condition [Rogalski 1990].

Beginners tend to use an iterative model for recursion. This model is compatible with tail-recursion, but fails in the more general case [Kurland 1989, Rogalski 1990]. For this reason, [Rogalski 1990] recommends that recursion be taught before iteration.

However, in a more detailed scrutiny of novice models of recursion, [Kahney 1989] found that while a large number of novices (> 50%) appear to have a iterative model, in fact most of them actually have no consistent model at all. [Kessler 1989] analyzed transfer between iteration and recursion, and found positive transfer from iteration to recursion, but no transfer from recursion to iteration. They conclude by recommending that iteration be taught before recursion.

Context of Use:	Notation
Justified by:	Empirical studies, observations of individual users

Examples: Many students expect a while loop to terminate as soon as its condition fails (daemon-exit) rather than waiting until the condition is tested at the “top of the loop” [Bonar 1989, Sleeman 1988].

Students often make the following errors related to loops [Putnam 1989, Sleeman 1988]:
• interpret a statement that is adjacent to (after) a loop as though it is contained within it;
• execute only the last statement inside a loop multiple times;
• attribute looping behavior to a begin-end block;
• believe that a variable holds more than one value and thus treat a conditional statement as a loop;
• believe that the for-loop control variable does not have a value inside the loop, or that it is acceptable to change its value inside the loop; and,
• interpreted the range of values on the for-loop control variable as a constraint on the values of a different variable inside the loop.

Cross References: 5-3. “Consistency with External Knowledge”
5-4. “Closeness of Mapping”
5-5. “Support for Planning”
5-6. “Naturalness of the Programming Language”
5-8. “Effectiveness of Notation is Task Dependent”
5-9. “Control Structures”

References: [Bonar 1989, Hoc 1989, Kahney 1989, Kessler 1989, Kurland 1989, Onorato 1986, Pirolli 1985, Putnam 1989, Rogalski 1990, Sleeman 1988, Soloway 1989, Wu 1991]

5-11. Support Direct Manipulation and Definition by Example

Some languages, such as cT [Sherwood 1988], and Turing [Cordy 1992] permit the user to interactively define the objects that will be manipulated by the program, and then to embed them directly in the program. In textual languages, this saves a lot of effort because writing a program to define these objects would be tedious [Lewis 1987]. Hypercard and Visual Basic invert the process, by having the programmer sketch the graphics and then attach programs to the graphics [Green 1990a]. However, when these methods are used, there is often a serious problem with the distinction between *use* and *mention* of the object (see examples below) [Smith 1992]. This distinction should be avoided [Lewis 1987, Smith 1992]. One way to achieve this is by modeling the system after the physical world, with the following implications: "a) [the system] must have object-oriented semantics, so that objects can directly present their own state and behavior, b) it must be dynamic, allowing incremental changes from the interface, c) it must be visual, so that all capabilities of the language are present in the interface, and d) it must avoid enforcing any kind of [distinction between use and mention of the object] [Smith 1992]."

Context of Use:	Notation, environment and metaphor
Justified by:	Expert opinion
Examples:	The distinction between use and mention can be seen by considering a button in a direct-manipulation interface. Pressing the button is a *use* – it causes the button to perform its action. However, when moving or resizing the button, clicking on it should not perform the action – this is *mention*. Often handles are provided for mention tasks, but this provides only one level – you can use the handles but you can not mention them [Smith 1992]. In BASIC, the distinction between use and mention comes up in `PRINT "Q:"; Q`, where first the name of the variable is printed, then its value. Students misinterpret `"Q:"` as [Putnam 1989]: • a comment that is not executed; • the same as the unquoted use of the variable; or, • referring to the very first value that was ever stored in the variable.
Cross References:	5-12. "Choosing a Paradigm"
References:	[Cordy 1992, Green 1990a, Lewis 1987, Putnam 1989, Sherwood 1988, Smith 1992]

5-12. Choosing a Paradigm

Most of the research in this report studies the classical imperative paradigm of computing where the user is in control of a single thread of execution. There are many other programming paradigms, including object-oriented, event-based, functional, programming by demonstration, graphical rewrite rules, autonomous agents, data flow, production system or rule-based programming, logic programming, parallel programming, etc. Some of these paradigms have achieved widespread use in research and professional software development communities. In other cases, only experimental systems have been developed to test a paradigm or a mixture of several paradigms. From a usability point of view, there is much room for investigation of this area, to determine the strengths and weaknesses of the various paradigms, and how the best features of multiple paradigms might be mixed into an effective novice programming system. Also, when introducing a new paradigm to people with some programming experience, there is a risk of negative transfer from the prior paradigm [Mendelsohn 1990, Siddiqi 1996, Wiedenbeck 1996].

Object oriented programming is widely advocated as a paradigm for quickly building programs from reusable components. However, this idea, when carried too far, has been found to have a detrimental impact on performance. Object oriented programming may have benefits for up to three levels of class hierarchy, but deeper hierarchies have been found to be difficult to work with [Daly 1996]. A cognitive phenomena called *conceptual entropy* may be the root cause of this problem [Dvorak 1994]. Object-oriented design is not necessarily a “natural” design method. Programmers have difficulty deciding which logical entities should be represented as objects and which as attributes of the objects [Détienne 1990]. Perhaps careful construction of the programming environment could assist users with these problems and limit the use of object-oriented programming to situations where it will be helpful.

Multiple inheritance may have additional advantages over single-inheritance object-oriented programming, but surveys of experienced programmers reveal mixed opinions. Some argue that it produces a more complex design, is more difficult to test, is more difficult to reuse, and is easy to abuse; while others argue that it produces a more appropriate design, and facilitates reuse and maintenance. There is little doubt that it adds complexity. An additional concern is that multiple inheritance is often implemented where it is inappropriate, resulting in object-oriented software that is more complex than is necessary. This leads to a recommendation to use multiple inheritance only where there is a strong case for using it [Daly 1995a, Daly 1995b].

Viewing procedures as “object-like entities” offers semantic power and syntactic elegance, but novice programmers view them with few “object-like” properties [Eisenberg 1987]. The authors suggest ways to improve instruction and the environment to overcome this. Note that this object-oriented view of procedures in a functional language is different than pure objects in object-oriented programming languages. [Rist 1996] describes the procedures in a functional language as encapsulations of goals with their plans; and points out that this encapsulation is orthogonal to the encapsulation of data with operations in an object-oriented language. Further, he states that goals and plans are not well captured in an object-oriented language.

Context of Use: Environment

Justified by: Empirical studies, informal observation of users, expert opinion.

Examples: KidSim [Cypher 1995, Smith 1995] uses graphical rewrite rules and programming by demonstration to provide an end-user programming system for symbolic simulations of agents in a two-dimensional grid. In KidSim, user testing revealed that arbitrarily deep hierarchies caused difficulties for children, so a one-level simple inheritance scheme was adopted [Smith 1994].

AgentSheets is a paradigm that consists of a large number of autonomous communicating agents organized in a grid [Repenning 1993]. This spatial metaphor supports the problem solving process, which includes creating and changing external representations of the problem as well as exploring problem spaces [Repenning 1994].

ToonTalk uses video-game animation in a city populated by robots as the means of creating and viewing programs [Kahn 1996]. It uses programming by example, but instead of automatic induction or learning, requires the user to introduce generality by removing details from the example.

LiveWorld is a programming environment based on rule-like agents that are responsive to their environment [Travers 1994]. It uses a novel object system that makes computational objects, such as behavioral rules, concrete and accessible like graphical objects.

ShopTalk enhances direct manipulation with natural language text, in order to overcome some of the limitations of direct manipulation in specifying objects and actions [Cohen 1989].

Cross References:
5-1. “Choose an Appropriate Metaphor”
5-3. “Consistency with External Knowledge”
5-5. “Support for Planning”
5-7. “Visual vs. Textual”
5-11. “Support Direct Manipulation and Definition by Example”
8-1. “Minimize Working Memory Load”

References: [Cohen 1989, Cypher 1995, Daly 1996, Daly 1995a, Daly 1995b, Détienne 1990, Dvorak 1994, Eisenberg 1987, Kahn 1996, Mendelsohn 1990, Repenning 1993, Repenning 1994, Rist 1996, Siddiqi 1996, Smith 1995, Smith 1994, Travers 1994, Wiedenbeck 1996]

5-13. Modularity and Abstraction

Abstraction of functionality into modules is a powerful programming concept. It can promote information hiding, reduce the amount of code that must be understood in detail, and provide a suite of primitives that can be composed to implement new functionality. When programmers understand code at an abstract level they are more likely to reuse that code in other appropriate places, and that reuse is more likely to be by invoking the code (making a procedure call), which is a more efficient form of reuse than making a copy of the code in the new context [Hoadley 1996]. But novices are not ready to use the abstraction tools which are emphasized by modern languages [Mendelsohn 1990].

Modular programming is often taught through a discipline known as top-down design, where the program is first described at an abstract, high level, then refined into a modular hierarchy [Wirth 1983]. However, hierarchically designed programs are not always easy to develop and comprehend [Curtis 1989, Perkins 1989]. Top-down strategies are difficult for novices because their spontaneous strategies or plans are based on concrete mental execution; action-oriented rather than object-oriented [Rogalski 1990]. And, taking modularity and abstraction to the extreme can interfere with locality and visibility (see “Locality and Hidden Dependencies” on page 243) [Green 1996]. One problem with comprehension of modular programs is that novices do not yet have the expert strategy of reading a program in a top-down, order-of-execution manner – instead they read the program like a book [Gellenbeck 1991b, Jeffries 1982, Wiedenbeck 1986b]. Novices focus on the very literal and concrete, rather than the abstract, hierarchical, general view used by experts [Onorato 1986]. An environment that helps the novice to read and understand the program in a modular fashion and to identify meaningful sections may alleviate this problem. Novices using such an environment make very effective use of modularity [Miller 1994].

A modular program can be modified faster than an equivalent non-modular program when at least one of the following conditions hold [Korson 1986]:

- modularity has been used to promote information hiding, which localizes changes;
- existing modules provide a suite of useful generic functions that can be composed to implement new functionality; or,
- the modification requires an extensive understanding and modification of the existing code.

However, modularity did not help in other cases, such as adding a new feature to a program.

Another kind of abstract thinking that is difficult for novices is writing a general solution to a problem rather than a solution that is specific to the situation (e.g. a program that sorts a list). This requires students to make a shift from value processing to variable processing; and to elaborate some of the control decisions that are not consciously made in solving a specific problem [Hoc 1990]. Also, a lack of abstraction is evident in the tendency of novices to code loops as sequential actions, *unrolled* [Hoc 1989]. Examples and analogies play an important role in learning and understanding, and explanations help learners to generalize the examples [Lewis 1987].

Context of Use:	Environment, notation, and instruction
Justified by:	Empirical studies, observations of users, expert opinion.
Examples:	The programming environment can support modularity and reduce its negative attributes by providing multiple views, such as call graph, outline, and class hierarchy views [Miller 1994, Roberts 1988]. Spreadsheets do not support modularity and abstraction very well. Abstraction is presented at a fixed level and hierarchical representations are not supported [Lewis 1987]. KidSim uses programming by demonstration to address the concrete vs. general abstraction problem. It allows users to create an abstract rule by demonstrating what that rule should do in a specific (concrete) situation. The system then automatically generalizes the specific rule into a more abstract one [Cypher 1995].
Cross References:	4-3. “Locality and Hidden Dependencies” 5-3. “Consistency with External Knowledge” 5-5. “Support for Planning” 5-6. “Naturalness of the Programming Language”
References:	[Curtis 1989, Cypher 1995, Gellenbeck 1991b, Green 1996, Hoadley 1996, Hoc 1989, Hoc 1990, Jeffries 1982, Korson 1986, Lewis 1987, Mendelsohn 1990, Miller 1994, Onorato 1986, Perkins 1989, Roberts 1988, Rogalski 1990, Wiedenbeck 1986b, Wirth 1983]

5-14. Cognitive Issues

There are several findings about cognitive aspects of programming which should be kept in mind.

Context of Use:	Environment, notation and instruction
Justified by:	Empirical studies, observations of individual users, expert opinion.

Examples:

Meta-cognitive strategies are used to select an operation when several different ones could be applied. They play an important role in effective programming. Users may benefit if the system either suggests a particular strategy or plan, or minimizes the number of situations where an operation must be selected from among multiple choices [Bell 1991]. However, the latter suggestion may conflict, for example, with a desire to support multiple looping strategies. As mentioned above (see "Avoid Subtle Distinctions in Syntax" on page 246), more planning is required when there are many different legal solutions to a problem [Gray 1987]. When more planning is required, it is more likely to cause backtracking, where the programmer is taken away from the progressive activity of coding. The programming environment could use an expert system to guide the novice in this decision making [Návrat 1993, Návrat 1996].

Experts are more likely than novices to develop complex high-level representations of the program. This happens a top-down fashion when looking at large units and fitting large pieces together, and in a bottom-up fashion when identifying chunks of code and deducing how they fit into the goal hierarchy [Boehm-Davis 1996]. Anything that the environment can do to assist novices in forming high-level representations may be helpful.

As mentioned above (see "Closeness of Mapping" on page 255), an abundance of low-level primitives is one of the great cognitive barriers to programming [Lewis 1987].

Another great difficulty of programming is that it is much more precision-intensive than other subjects [Perkins 1988].

Students do not spontaneously develop general problem-solving skills from programming experiences (transfer effect) [Olson 1987]. There is only weak evidence that programming is a medium that creates new ways of dealing with existing knowledge, and no evidence that through programming practice, children develop cognitive skills that are identifiable and transferable to other situations such as: analogical and temporal reasoning, mathematical operations, planning of action, error correction, and development of logical and spatial operations [Mendelsohn 1990]. Many studies of children using LOGO confirm this absence of transfer [Dalby 1985, Nickerson 1985, Pea 1984, Perkins 1985]. However, when a skill is explicitly taught in the framework of programming with an emphasis on transfer, transfer to other domains (e.g. debugging skills, expository writing, spatial cognition skills, planning) can occur [Carver 1988, Carver 1987, Goldenson 1996, Lee 1993, Lehrer 1988, Mayer 1987]. In addition to acquiring the programming skill, the student must also recognize the relevance of the acquired knowledge to the new domain [Fay 1988]. Successful demonstrations of transfer result from effective teacher mediation rather than simply exposure to programming [Clements 1993, Mayer 1988].

Users who are averse to risk are more successful in structure editor based programming environments, where syntax errors are not possible [Neal 1987].

Acquiring the syntax of a language is difficult for children. The cognitive demands of getting the syntax right thus interfere with the task of getting the semantics right. This phenomenon has been observed in other domains such as writing. Systems that attempt to relieve the syntactic burden on the student, such as a flexible language syntax or a structure editor, should permit the student to devote more resources to the semantics of the programming task [Fay 1988].

Although computer programming is often characterized as a set of non-interacting subtasks (e.g. specification, design, planning, coding, testing, debugging, documenting, etc.), in practice there are substantial interactions among them. “This is a fundamental feature of programming [that arises] from the cognitive characteristics of the subtasks [and] the high uncertainty in programming environments... [Pennington 1990].”

Knowledge and problem-solving strategies work together in programming. Fragile knowledge (partial, hard to access, or misused) can be compensated by effective strategies. Exploratory use of the language and other elementary problem solving strategies should be explicitly taught [Perkins 1986]. In a course that helped students to form a clear mental model of the computer, provided them with heuristics to helm the conceptualize and organize the elements of the programming language, and equipped them with problem solving tools and strategies, students performed better that a control group that did not use these techniques [Perkins 1988].

Cross References:	4-5. “Avoid Subtle Distinctions in Syntax” 4-6. “Support Incremental Running and Testing with Immediate Feedback” 5-4. “Closeness of Mapping” 5-5. “Support for Planning” 5-9. “Control Structures” 5-10. “Loop and Recursion Control Structures” 5-13. “Modularity and Abstraction” 8-1. “Minimize Working Memory Load”
References:	[Bell 1991, Boehm-Davis 1996, Carver 1988, Carver 1987, Clements 1993, Dalby 1985, Fay 1988, Goldenson 1996, Gray 1987, Lee 1993, Lehrer 1988, Lewis 1987, Mayer 1988, Mayer 1987, Mendelsohn 1990, Návrat 1993, Návrat 1996, Neal 1987, Nickerson 1985, Olson 1987, Pea 1984, Pennington 1990, Perkins 1985, Perkins 1986, Perkins 1988]

5-15. Instructional Design

Here are some educational observations that can be used to guide the design of the environment.

Context of Use:	Instruction
Justified by:	Empirical studies, observations of individual users, expert opinion

References:

[Davis 1993] presents a model of learning to program where students develop a system of rules (some incorrect) about programming, and apply them either consistently or intermittently. An effective intervention may be to encourage students to reflect on their rules and relate them to feedback received from the computer. The environment could be built to support this reflective phase of knowledge acquisition.

One of the areas of difficulty for novices is orientation to programming: finding out what programming is for, what problems can be tackled, and what the advantages are. Another is coming to terms with the duality of the computer as the manager of program creation vs. the machine executing the program. The latter problem is exacerbated by early examples that print text to the screen, where the output of the program looks almost exactly like the program itself [du Boulay 1989a]. Perhaps better examples could be chosen.

[du Boulay 1989a] also points out that another crucial concept that is confusing for novices is the computer's rigidity, which can be confused by the way the computer is described (see "Consistency with Metaphor" on page 252 for more details).

Teachers should [Hoc 1990]:
• design situations that require learners to solve programs in a general way, rather than specific to a particular situation;
• be aware of the kinds of real-world solutions that students may attempt to transfer to the programming task, so that they may be reinforced or suppressed as appropriate; and,
• provide direct, immediate feedback about the way that the learner adapts the real-world plan to the programming situation.

[Papert 1980] uses computing as a medium, a support for elaborating environments in which the child constructs his/her own knowledge. Discovery and exploration are emphasized over a structured curriculum. [Heller 1986] investigated the difference between a structured Logo curriculum and a experiential Logo learning environment, and found that the structured environment is better for obtaining thorough knowledge in a limited time, while the experiential environment is better for a broadly framed "growth experience”. [Littlefield 1988] confirmed that a structured approach was better than an unstructured approach for language mastery, and also found that a mediated-teaching approach produced mastery levels equivalent to the structured approached. However, the mediated approach resulted in superior performance on near-transfer tasks than the structure approach, which in turn was superior to the unstructured approach.

Cross References:	4-6. “Support Incremental Running and Testing with Immediate Feedback” 5-2. “Consistency with Metaphor” 5-3. “Consistency with External Knowledge” 5-5. “Support for Planning” 5-14. “Cognitive Issues”
References:	[Davis 1993, du Boulay 1989a, Heller 1986, Hoc 1990, Littlefield 1988, Papert 1980]

6. User Control and Freedom

“Users often choose system functions by mistake and will need a clearly marked “emergency exit” to leave the unwanted state without having to go through an extended dialog. Support undo and redo [Nielsen 1994].”

The research in this section extends the above interpretation of “user control and freedom” to include issues of flexibility in the programming system. Giving control and freedom to users will make it easier for them to accomplish the programming task in their own ways.

6-1. Avoid Requiring Premature Commitment

A modern view of programming, where programs are developed in an exploratory, opportunistic, incremental fashion, requires that the programming system allow programmers to postpone decisions until they are ready for them. The system should avoid situations where correct generation of a piece of code requires subsequent pieces to be known. For example, tidy layout in some graphical programming languages requires the user to anticipate the space requirements of parts of the program that are not yet written [Green 1990b, Green 1987, Green 1996].

Context of Use:	Environment, notation
Justified by:	Informal observation of users, expert opinion
Examples:	Early in the code generation task, structure editors are good at reducing the problem of premature commitment, because they allow the programmer to leave holes where details can be filled in later [Green 1996]. However, later in the programming task, when modification is more prevalent than generation of new code, structure editors can make it difficult to back out of an earlier choice, thus exhibiting premature commitment [Green 1990b]. Structure editors that permit editing the program textually as well as structurally can avoid the latter problem (e.g. electric-C mode in Emacs, or the MacGnome structure editors [Miller 1994]). [Green 1996] uses cognitive dimensions to identify the following examples of premature commitment: • Text based languages require premature commitment at the structural level – they encourage development of the program in a linear order by adding text at the growing tip, rather than leaving holes to be filled in later. • Visual languages are less demanding about development order, but as mentioned above they require guess-ahead at the layout level – without careful lookahead, layout will become messy and is difficult to correct.
Cross References:	4-6. “Support Incremental Running and Testing with Immediate Feedback” 5-5. “Support for Planning” 5-7. “Visual vs. Textual”
References:	[Green 1990b, Green 1987, Green 1996, Miller 1994]

6-2. Viscosity

Viscosity is a measure of how much effort is required to make a small change to the program [Green 1996]. The final text of a program rarely corresponds to the order it was generated; therefore revision is intrinsic in programming [Davies 1996]. [Fitter 1979] cites a principle of *revisability* in good notational schemes: a system should make it easy to revise existing code in a program. Independent of other factors, it is desirable to minimize viscosity. As mentioned above (see “Avoid Requiring Premature Commitment” on page 281), a modern view of programming, where programs are developed in an exploratory, opportunistic, incremental fashion, requires that the programming system allow easy additions or changes to existing code [Green 1990b, Green 1996].

As mentioned above (see “Locality and Hidden Dependencies” on page 243), [Lewis 1987] proposes replacing *programming by synthesis* with *programming by modification*, where a library of examples is provided from which the programmer chooses an appropriate one for a starting point, identifies needed modifications, then modifies it to suit the current need. This emphasis on modification of existing code elevates viscosity as an important factor. However, [Nardi 1993] claims that programming by modification is not any more natural than other approaches to programming.

Context of Use:	Notation
Justified by:	Empirical studies, observation of individual users
Examples:	Visual programming languages have a high viscosity. [Green 1996] measured an order of magnitude increase in time to make a small change in the LabView visual programming language than in a textual language. In order for the programmer to preserve readability, LabView required many “enabling” steps before the goal could be addressed. Adding a line of code to a Basic program may require many lines to be renumbered, resulting in high viscosity. Sometimes a small change to a program has a domino effect, requiring many additional non-local changes. In object-oriented programming there is less of this cascading of changes, resulting in reduced viscosity [Green 1990b]. Spreadsheets have low viscosity: changes to a part are not constrained by other parts [Lewis 1987]. However, they are difficult to redesign when attempting to adapt another user’s spreadsheet to one’s own task.
Cross References:	4-3. “Locality and Hidden Dependencies” 4-6. “Support Incremental Running and Testing with Immediate Feedback” 5-7. “Visual vs. Textual”

	5-12. “Choosing a Paradigm” 6-1. “Avoid Requiring Premature Commitment” 6-3. “Support Secondary Notation”
References:	[Davies 1996, Fitter 1979, Green 1990b, Green 1987, Green 1996, Lewis 1987, Nardi 1993]

6-3. Support Secondary Notation

Secondary notation is information that is embedded in the program text that is not part of the syntactic structure that is meaningful to the system [Petre 1992]. There is a huge amount of important information that is not actually part of the program [Berlin 1993, Green 1995]. Experts use comments, white space, and typography to carry semantic domain knowledge about the program, and at least some of these benefit novices too [Gilmore 1986, Payne 1984, Riecken 1991]. The most common kind of secondary notation in textual languages is spatial layout through indentation and alignment [Gellenbeck 1991a]. However, the effect of spatial layout is less important than a good choice of notation [Curtis 1988]. Spreadsheet users make use of visual imagery in planning manipulations, implying that mental images of layout is important [Saariluoma 1994].

Indentation is the principle means of spatial representation in Pascal and other textual languages [Cunniff 1987]. When used consistently, indentation has been shown to improve comprehension [Cunniff 1989, Kesler 1984, Miara 1983, Vessey 1984]. Note that when indentation is used correctly and consistently, it is redundant with curly braces in C [Baecker 1986]. However, indentation can interfere with locality by breaking up semantic units in favor of syntactic units [Shneiderman 1986]. Color can supplement indentation in assisting the user to understand control flow [Van Laar 1989].

Textual languages allow a substantial amount of secondary notation, while visual languages obscure attempts to use grouping as a secondary notation [Green 1996]. As mentioned above (see “Use Signalling to Highlight Important Information” on page 240), secondary notation should be used to improve access to information that is needed but obscured [Green 1990b]. The value of secondary notation implies that the environment must facilitate it, by allowing the user flexibility on these details, and perhaps by explicitly supporting the recommendations in [Gellenbeck 1991a]: modules should be preceded by 1-3 lines of preview statements; and module names should be short, mnemonic, derived from the preview statement, and begin with a verb.

Context of Use:	Notation and environment
Justified by:	Empirical studies, expert opinion
Examples:	Comments, white space, and typography are examples of secondary notation that should be supported in the programming system.
	Meaningful variable names aid comprehension [Gellenbeck 1991b].
	In a study using graphical programs, novices were not able to extract the information in secondary notation that would have assisted their comprehension [Green 1991]. Training is required in order for them to exploit secondary notation.
	Python uses indentation for lexical scoping, eliminating the redundant use of braces or begin-blocks [Watters 1995].

Cross References:	4-1. “Use Signalling to Highlight Important Information” 4-3. “Locality and Hidden Dependencies” 5-5. “Support for Planning” 5-7. “Visual vs. Textual” 5-9. “Control Structures” 5-10. “Loop and Recursion Control Structures” 5-15. “Instructional Design” 6-1. “Avoid Requiring Premature Commitment” May conflict with objectives of 4-4. “Beware of Misleading Appearances”
References:	[Baecker 1986, Berlin 1993, Cunniff 1987, Cunniff 1989, Curtis 1988, Gellenbeck 1991a, Gellenbeck 1991b, Gilmore 1986, Green 1990b, Green 1995, Green 1996, Green 1991, Kesler 1984, Miara 1983, Payne 1984, Petre 1992, Riecken 1991, Saariluoma 1994, Shneiderman 1986, Van Laar 1989, Vessey 1984, Watters 1995]

7. Consistency and Standards

“Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions [Nielsen 1994].”

The research in this section investigates internal consistency of the programming language. Consistency with the outside world is discussed in the section “Match Between System and the Real World” beginning on page 249. As mentioned there, [Payne 1986] describes a formal method for assessing both kinds of consistency.

7-1. Consistency in Notation

The language should be self-consistent, and its rules should be uniform [du Boulay 1989b]. It should abide by any suggestions that can be derived from other places in the language, so that learners can infer one part of the language from another part [Green 1996]. It should minimize exceptions so that generalization of rules results in correct notation [du Boulay 1989a]. Conditionals with extra cues help both novices and experts [Sime 1977c]. As mentioned above (see "Avoid Subtle Distinctions in Syntax" on page 246), novices get confused when there are two different syntaxes to accomplish the same effect [Eisenberg 1987].

The meanings of keywords should be context independent. Novices are less likely than experts to organize language keywords in a meaningful way. Instead, they tend to focus on surface features [McKeithen 1981]. This argues against gratuitous re-use of the same keyword for different concepts.

Context of Use:	Notation
Justified by:	Empirical studies, analysis of frequent novice errors, expert opinion
Examples:	Syntactic consistency can be enforced by having all control structure take the form `X ... end X` [Cordy 1992].

The following are some examples of violations of consistency in notation:

In the Pascal language, all procedures end with semi-colon except the very last one which ends with a period, all statements end with a semicolon unless preceding an `else` or `until` statement, and lists of parameters are separated by semicolons in the declaration of a procedure and by commas in the call to the procedure.

In C, there are three different kinds of braces used in various situations: `{}`, `()`, and `[]`. They are not interchangeable, and sometimes they are mixed in an inconsistent way (see "Avoid Subtle Distinctions in Syntax" on page 246).

Pascal is not syntactically consistent in its control structures. Most of them terminate with `end`, but the `repeat` statement does not.

Many novice bugs arise out of inconsistency in the way the language treats different data types [Spohrer 1986b]. For example, white space is treated differently when reading into a numeric variable than it is when reading into a character variable [Spohrer 1986a].

The keyword `static` in C++ has many different meanings depending on context.

Exceptions:	Even when a language embraces consistency, students may not appreciate it. For example, in LISP the rules for evaluation are consistent, yet students adopt a series of special-case rules for certain control structures such as `cond`.
Cross References:	4-4. “Beware of Misleading Appearances” 4-5. “Avoid Subtle Distinctions in Syntax” 5-2. “Consistency with Metaphor” 5-3. “Consistency with External Knowledge”
References:	[Cordy 1992, du Boulay 1989a, du Boulay 1989b, Eisenberg 1987, Green 1996, McKeithen 1981, Sime 1977c, Spohrer 1986a, Spohrer 1986b]

8. Recognition Rather Than Recall

"Make objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate [Nielsen 1994]."

This section addresses the memory demands of programming.

8-1. Minimize Working Memory Load

Working memory limitations account for a large part of the inferior performance of novice programmers [Anderson 1985]. While experts are good at utilizing external memory to relieve their memory load, novices rely extensively on working memory. This indicates that for novices it is important that the environment minimize memory load, since they do not have the fallback of externalization [Davies 1993, Davies 1996]. TEd addresses this problem by maintaining a visual record of all edits [Ormerod 1996]. It is claimed that this supports display-based problem solving because it acts as an external repository of important programming knowledge, and it cues the programmer to focus on unsatisfied goals.

Context of Use:	General
Justified by:	Empirical studies
Examples:	Neither visual programming languages nor textual languages are good at supporting “display-based” problem solving, where the system’s display is used as a memory aid, reducing demands on working memory [Green 1996].
Cross References:	5-7. “Visual vs. Textual” 6-1. “Avoid Requiring Premature Commitment”
References:	[Anderson 1985, Davies 1993, Davies 1996, Green 1996, Ormerod 1996]

9. Aesthetic and Minimalist Design

“Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility [Nielsen 1994].”

The research in this section investigates conciseness.

9-1. Principle of Conciseness

[Cordy 1992] describes a principle of conciseness, which argues against redundant symbols such as program preambles, punctuation, and explicit declaration of variables and their types. Elimination of punctuation addresses a problem with the misplaced use of syntax which is described above (see “Avoid Subtle Distinctions in Syntax” on page 246). But if, for example, punctuation is replaced with line breaks as a statement separator, the problem of wrapping long lines must be handled sensibly.

Another aspect of conciseness is to allow optional information, with intelligent defaults [Cordy 1992]. Programming system should be flexible in allowing the user to elide undesired details and just fill in the obvious details, to stop requiring exact truth and instead allow an executable “cognitive approximation” to the solution [Lewis 1987].

However, conciseness can be subverted by a desire for elegance or parsimony of primitives. This can lead to absurdities. For example, early versions of Prolog did subtraction by inverse addition [Green 1990a]. [Mendelsohn 1990] cautions not to take *economy* and *elegance* as virtues in their own right: these are misplaced in designing languages for novices. “In looking for ever more abstracted ways to express behavior, modern languages have excised most clues to goal and purpose that are essential to novice understanding [Bonar 1990].” Novice programmers are more verbose than expert programmers in describing tasks to computers or to humans [Onorato 1986]. Thus experts have the edge in conciseness and preciseness.

Context of Use:	Notation
Justified by:	Empirical studies, expert opinion
Examples:	The type of a variable could be inferred from its initialization, eliminating the necessity to declare its type.

Pascal has a large program preamble that only contributes one meaningful piece of information, the name of the program, “`p`”:

```
Program p (input,output);
```

APL takes conciseness to the extreme, at the expense of an excessive number of cryptic primitives. But, as mentioned above (see “Closeness of Mapping” on page 255), an abundance of primitives is problematic [Lewis 1987].

HyperTalk is a compromise, because optional syntax allows the same expression to be expressed concisely or verbosely, depending on the programmer’s preference. However, as mentioned above (see “Avoid Subtle Distinctions in Syntax” on page 246), more planning is required when there are many different legal solutions to a problem [Gray 1987].

Exceptions:	Conciseness should be balanced with the findings of [Sime 1977c] that more verbose control structures help both beginners and novices to manage flow of control.
Cross References:	“Use Signalling to Highlight Important Information” on page 240 4-5. “Avoid Subtle Distinctions in Syntax” 5-3. “Consistency with External Knowledge” 5-4. “Closeness of Mapping”
References:	[Bonar 1990, Cordy 1992, Gray 1987, Green 1990a, Lewis 1987, Mendelsohn 1990, Onorato 1986, Sime 1977c]

10. Help Users Recognize, Diagnose, and Recover from Errors

“Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution [Nielsen 1994].”

The research in this section investigates some common kinds of bugs and ways that the system can help the user identify and fix them.

10-1. Support for Testing and Debugging

Testing and debugging are areas of difficulty for novices [du Boulay 1989a]. As mentioned above (see “Support Incremental Running and Testing with Immediate Feedback” on page 247), [du Boulay 1989b] claims that the computational machine should reveal its internal workings in terms of the language itself. This can be interpreted as a call for a source-level debugger and tracer with data visualization. [Mendelsohn 1990], and [Eisenstadt 1989] describe such systems for Prolog, and [Miller 1994] describes one for Pascal.

Research by [Gugerty 1986a, Gugerty 1986b, Kessler 1986, Nanja 1987] observed that novices tend to add new bugs to the program while debugging. This suggests that the environment should provide a checkpointing feature, or a selective undo feature, to help the user recover from these errors.

A survey of experienced programmers found that the most common root cause of bugs was memory getting clobbered or used up [Eisenstadt 1993]. Anything the environment can do to prevent or detect these problems would be helpful, especially since this kind of bug is more difficult to detect because often there is chasm – a distance in time and code proximity – between the cause and the effect of the bug. That survey also found that using a debugger and instrumenting the code with print statements were much more common than code-reading in expert debugging, suggesting that a good debugger is essential.

However, novices who are able to program do not automatically gain debugging skills in the process of learning to program, suggesting that it would be useful for debugging strategies to be taught or for the environment to be proactive in suggesting strategies.

Context of Use:	Environment
Justified by:	Empirical studies, observations of individual users, expert opinion
Examples:	Spreadsheets do not support debugging very well. The underlying formulas are not revealed unless explicitly made visible, so only one cell can be examined at a time; and variables are usually labelled with their cell location rather than a meaningful or mnemonic name. Many novice bugs are caused by boundary or fence-post problems, such as: • off-by-one bugs; • not permitting the value zero where it should be permitted, or permitting it where it should not be permitted; • the decision whether a boundary value should be handled as a special case or by one of the conditions that it divides; • confusion between the number of values in a range and the highest value in a range: • drawing incorrect parallels between constructs that have different boundary values, such as hours ranging from 1..12, but minutes ranging from 0..59 rather than 1..60.

To the extent that the environment can help to clarify these confusions, novice productivity should be enhanced [Spohrer 1986a, Spohrer 1986b].

A major source of bugs is failure to guard against illegal or missing data [Cunniff 1989].

Students sometimes interpret the assignment statement `A:=B` as a swap operation, a print statement, a no-op, or a boolean comparison operation [Sleeman 1988].

Cross References:	4-3. “Locality and Hidden Dependencies” 4-6. “Support Incremental Running and Testing with Immediate Feedback” 5-15. “Instructional Design”
References:	[Cunniff 1989, du Boulay 1989a, du Boulay 1989b, Eisenstadt 1993, Eisenstadt 1989, Gugerty 1986a, Gugerty 1986b, Kessler 1986, Mendelsohn 1990, Miller 1994, Nanja 1987, Sleeman 1988, Spohrer 1986a, Spohrer 1986b]

11. Help and Documentation

“Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user’s task, list concrete steps to be carried out, and not be too large [Nielsen 1994].”

The research in this section investigates a kind of documentation called guiding knowledge.

11-1. Provide Guiding Knowledge

Guiding knowledge is a brief document that describes everything a naive user needs to know about the system [Bell 1994]. It describes the metaphor, explains general concepts of the system and its use, and contains advice about how to go about solving problems. Examples and analogies play an important role in understanding [Lewis 1987]. Users will have difficulty if there are hidden assumptions, if there is any necessary information missing from the guiding knowledge, if the guiding knowledge is not consistent with itself or the system's metaphorical model, or if the guiding knowledge does not convince the user that the recommended plans will work. However, it is desirable for the guiding knowledge to be brief, because it is the initial hurdle to using the system. This argues for a good metaphor, because it will be easily explained and consistent, so that the guiding knowledge can be brief.

Context of Use:	Documentation and metaphor
Justified by:	Based on the *programming walkthrough* method for assessing the programming language designs [Bell 1994], which in turn was based on the *cognitive walkthrough* method for evaluating user interfaces [Lewis 1990, Polson 1992].
Examples:	The Macintosh introduced the mouse, menus, icons, and windows in a direct-manipulation graphical user interface. Despite the fact that most new users were learning a radically new system, the guiding knowledge was remarkably small: a thin manual and a short online guided tour.
	When the guiding knowledge suggests a plan for solving a particular problem, but does not convince the user that this plan will work, users apparently believe that they do not understand the guiding knowledge, and begin searching for alternative plans that are "better". This may be related to meta-cognitive strategies (see "Cognitive Issues" on page 275).
Examples:	5-1. "Choose an Appropriate Metaphor"
	5-5. "Support for Planning"
	5-14. "Cognitive Issues"
References:	[Bell 1994, Lewis 1987, Lewis 1990, Polson 1992]

12. Conclusions

This report attempts to organize the existing research about novice programmers in a way that will facilitate its use in guiding the design of new programming systems. The authors welcome comments and additions to this material.

There are a number of questions that are not addressed by the research we were able to find. For example:

- How does verbosity affect novice programming effectiveness? Are languages like HyperTalk, with optional extra words that enhance natural-language readability, more effective than terse languages, and what new problems do they exhibit?
- What are the relative strengths and weaknesses of the various paradigms of programming, such as the event-driven model?
- To what extent can careful design of the programming environment solve many of the problems that have been identified in this report?

We hope that future research will address these questions.

In addition to the results summarized here, there are general Human-Computer Interaction (HCI) principles that apply to all computer systems, including programming systems (e.g., [Macaulay 1995, Nielsen 1994, Tognazzini 1992]). Designers of programming systems should consider these general HCI principles as well as the issues that are directly related to programming.

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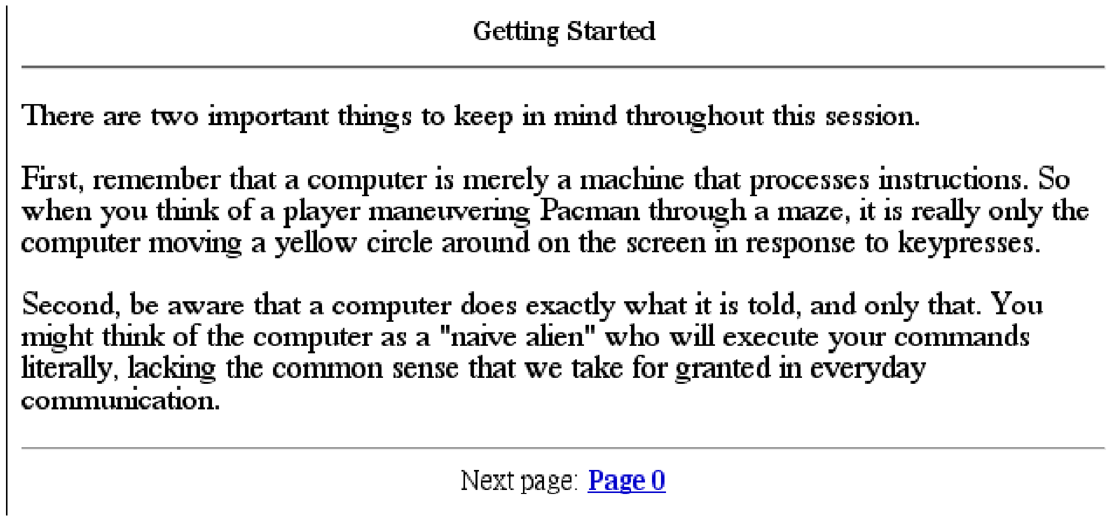
APPENDIX D

Materials from Study 1

The following pages contain the materials presented to the participants in Study One, followed by the rating form and instructions given to the analysts.



Getting Started

There are two important things to keep in mind throughout this session.

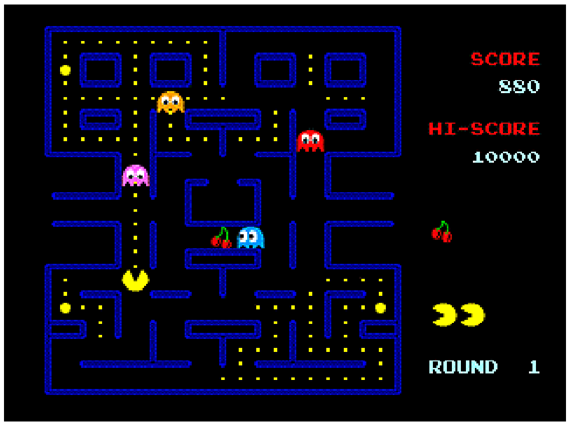
First, remember that a computer is merely a machine that processes instructions. So when you think of a player maneuvering Pacman through a maze, it is really only the computer moving a yellow circle around on the screen in response to keypresses.

Second, be aware that a computer does exactly what it is told, and only that. You might think of the computer as a "naive alien" who will execute your commands literally, lacking the common sense that we take for granted in everyday communication.

Next page: Page 0

Page 0

Pacman was an early arcade game that was popular in the 1980's.



Do this: If you are not already familiar with Pacman, please familiarize yourself with the game.

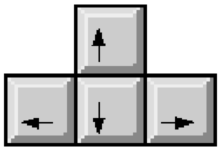
Page 1 of 9

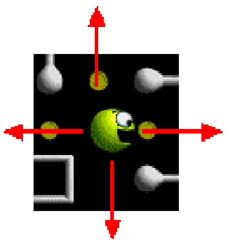
I am the computer. You are the computer programmer.

Do this: Give me, the computer, an overall description of the Pacman game.

Page 2 of 9

Sometimes Pacman moves around on the screen.

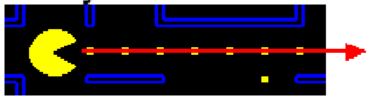




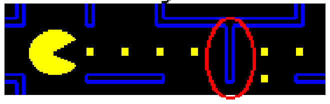
Do this: Describe what I (as the computer) should do to make PacMan do this.

Page 3 of 9

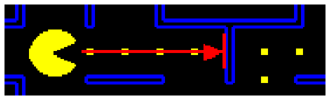
Usually Pacman moves like this.



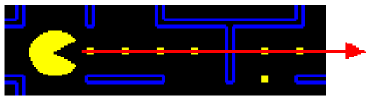
Now let's say we add a wall.



Pacman moves like this.



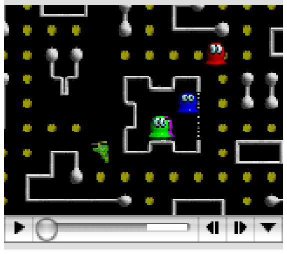
Not like this.

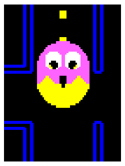


Do this: Write a statement that summarizes how I (as the computer) should move Pacman in relation to the presence or absence of other things.

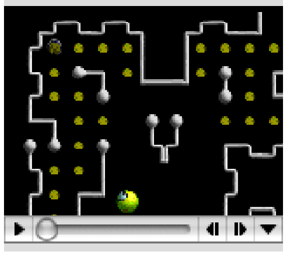
Page 4 of 9

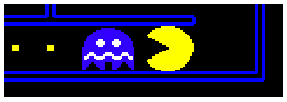
Sometimes Pacman dies.





But sometimes Pacman gets points.

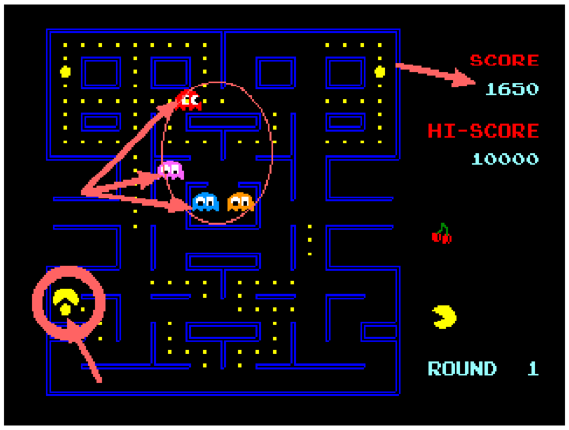




Do this: Write a statement that explains how I (as the computer) should decide which should happen.

Page 5 of 9

Before:



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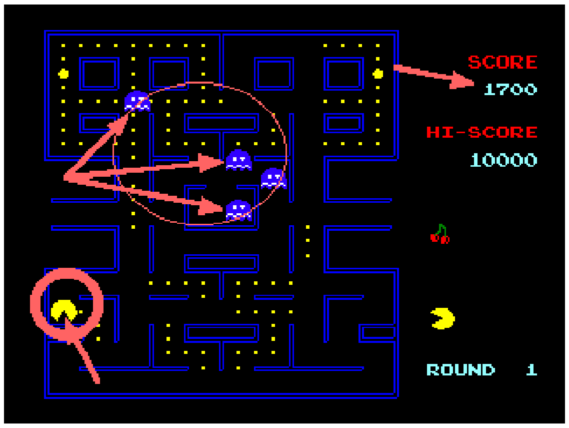
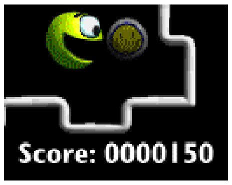


Do this: Write a summary that describes what I (as the computer) should do in this situation.

Page 6 of 9

Before:



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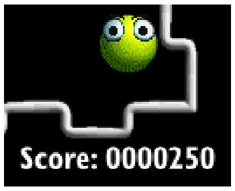

Do this: Describe in detailed steps what I (as the computer) should do to accomplish all of the things that are happening here.

Page 7 of 9

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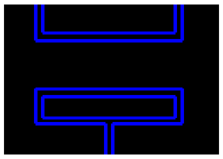
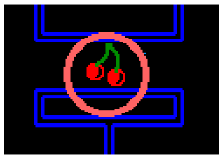
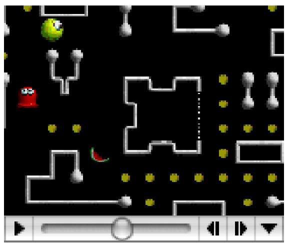


After:

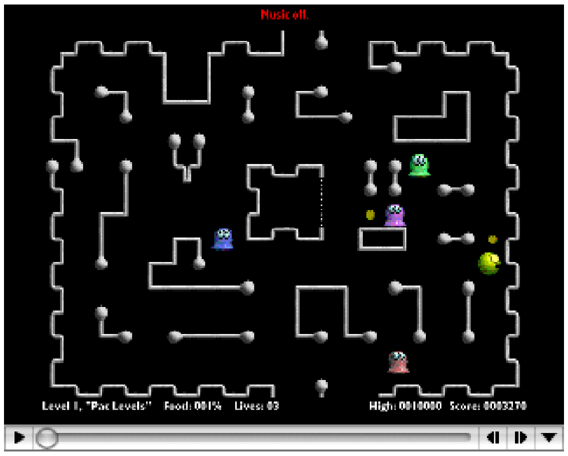




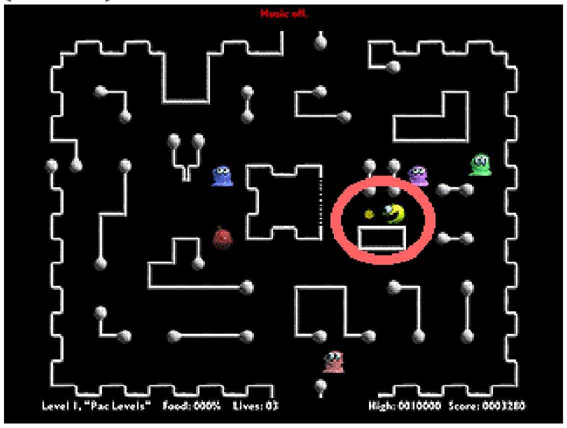
Do this: Describe this event in relation to the game (what I as the computer should do to handle the fruit, when I should do it, etc.)

Page 8 of 9

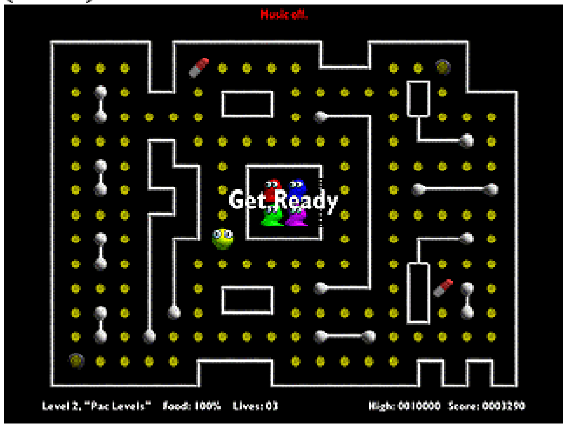
Sometimes this happens:


Music off.
Level 1, "Pac Levels"   Food: 001%   Lives: 03
High: 0010000   Score: 0003270

(Before:)

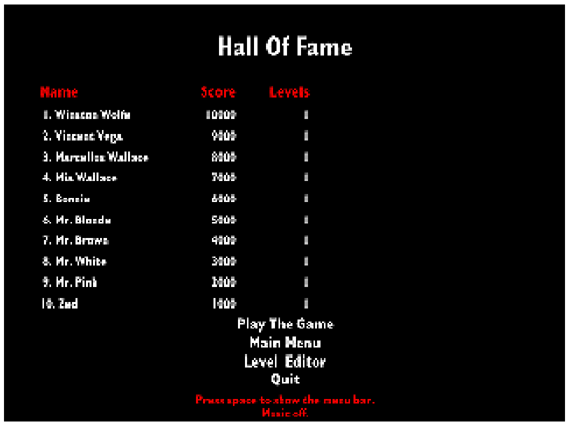

Music off.
Level 1, "Pac Levels"   Food: 000%   Lives: 03
High: 0010000   Score: 0003280

(After:)


Music off.
Get Ready
Level 2, "Pac Levels"   Food: 100%   Lives: 03
High: 0010000   Score: 0003290

Do this: Describe what I (as the computer) should do to make this happen, including how I should decide the correct time to do it.

Page 9 of 9


Hall Of Fame

Name	Score	Levels
1. Winston Wolfe	10000	1
2. Vincent Vega	9000	1
3. Marcellus Wallace	8000	1
4. Mia Wallace	7000	1
5. Bonnie	6000	1
6. Mr. Blonde	5000	1
7. Mr. Brown	4000	1
8. Mr. White	3000	1
9. Mr. Pink	2000	1
10. Zed	1000	1

Press space to show the menu bar.
Music off.

Before: (in case you can't read the above)

```
NAME                        SCORE    LEVELS
1. Winston Wolfe            10000    1
2. Vincent Vega             9000     1
3. Marcellus Wallace        8000     1
4. Mia Wallace              7000     1
5. Bonnie                   6000     1
6. Mr. Blonde               5000     1
7. Mr. Brown                4000     1
8. Mr. White                3000     1
9. Mr. Pink                 2000     1
10. Zed                     1000     1
```

Then someone named "Vincent Vega" plays the game and finishes with a score of 6110. This is good enough for a certain place in the high scores list. This addition may affect the rankings of other high scores.

After:

```
NAME                        SCORE    LEVELS
1. Winston Wolfe            10000    1
2. Vincent Vega             9000     1
3. Marcellus Wallace        8000     1
4. Mia Wallace              7000     1
5. Vincent Vega             6110     1
6. Bonnie                   6000     1
7. Mr. Blonde               5000     1
8. Mr. Brown                4000     1
9. Mr. White                3000     1
10. Mr. Pink                2000     1
```

Do this: Describe in detailed steps what I (as the computer) should do to determine where to put Vincent's score, and all of the other changes I should make to the high scores list.

Instructions to Raters

You are helping us to analyze data from a study of children's solutions to a programming task. The children were shown nine scenarios, and asked to write instructions for the computer, using their own words and pictures. We are investigating the natural ways that non-programmers express these instructions.

Your task is to recognize various patterns or concepts that might be present in the children's solutions, and to count them on the attached rating form. Please fill out one rating form for each of the 14 students.

The rating form asks a series of questions, and for each question lists some of the patterns or concepts that you might see in the student's solution. Each time you find one, please put a tick-mark on the line for that pattern, in the slot corresponding to the problem number that the student was working on when he/she generated it.

For example, if you see five occurrences of explicit loops in a student's answer to problem 9, you would put five ticks in slot 9 of line 4a.

Please do this counting at the level of sentences or statements. To make your analysis easier, you may wish to first make a pass through each student's answers, marking the boundaries between sentences. After you have identified the individual sentences, it will be easier to decide which category, if any, each one will fall into.

Note: For questions #1 and #2 on the rating form, please count every statement/sentence in the student's solution. For the rest of the rating form, it is sufficient to count only those sentences that are relevant to the question we're asking you.

Please read through the questionnaire before beginning, to familiarize yourself with what we are asking. For each question we ask you, there is also an "other" line, where you can mark other patterns or concepts that aren't listed. Also, if you see something interesting that is not covered by any question on the form, please describe it in the space at the end of the rating form.

You should feel free to write and make notes on the student solutions.

There are 14 students, and each one has a unique id number. But the id numbers are not contiguous.

Some students skipped some of the problems, or answered one question in the process of answering a prior question. Please rate the responses according to the problem that the student was actually working on at the time the response was generated.

If you have any questions, please contact:

John Pane	268-8078	pane@cs.cmu.edu
Brad Myers	268-5150	bam@cs.cmu.edu

RATER'S NAME __________ STUDENT # _________

1. Please count the number of times you see these various styles of programming. For this question, please count every statement/sentence in the student's solution.

a) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Production Rules (or event-based): where operations are preceded by "when", "if", or "after"(used as to mean 'when', not as to mean 'a long time after')

Example:When it begins to get dark, turn your headlights on.

b) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Constraint Style: where operations are expressed as relations that should always hold.

Example:Car must always be above the road.

c) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Imperative Style: where a sequence of operations is specified.

Example:Look to the left; Look to the right; Take one more look to the left;

Pull out to enter the intersection.

d) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Other (please specify) ____________________

2. Please count the number of times you see these various perspectives. For this question, please count every statement/sentence in the student's solution.

a) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Player's perspective: (including playing strategies)

Example:To get bonus points, I/you need to win the game within 2 minutes.

b) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Programmer's perspective:

Example:If the game is won within 2 minutes, give bonus points to the player.

c) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Other (please specify) ____________________

3. Please count the number of times the student uses these various methods to express concepts about multiple objects.

(The situation when an operation affects some or all of the objects, or when different objects are affected differently.)

a) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Think of them as a set or subsets of entities and operate on those, or specify them as plurals.

Example:Buy all the books that are red.

b) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Use iteration (i.e. loop) to operate them explicitly.

Example:For each book, if it is red, buy it.

c) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Other (please specify) ____________________

4. Please count the number of iteration or looping constructs in the student's solution.

a) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Explicit. (Repeat, while, and so on, for, etc.)

Example:He repeated saying those words several times.

b) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Implicit. (only terminating condition is specified)

Example:I will wait until you start.

c) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Other (please specify) ____________________

5. In programming languages, a common form is "IF ... THEN ... ELSE", do you see any examples of having an ELSE (or equivalent) clause in the student's solution?

a) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Yes, using the word ____________________

6. Please count the number of times the student uses these various methods to handle conditions with various options.

a) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

By specifying the general case first and then modifying it with exceptions (using "unless", "but if", "except", etc.)

Example:When it snows you should drive slowly. But if you have snow tires you can drive a little faster.

b) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

By specifying a more complex boolean expressions (and, or, not).

Example:When it snows AND you have snow tires, you can drive a little faster OR when it snows AND you do NOT have snow tires, you should drive slowly.

c) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

By specifying mutually exclusive conditions.

Example:If you have snow tires, you can drive a little faster.

If you do NOT have snow tires, you should drive slowly.

d) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Other (please specify) ____________________

7. Please count he number of times the student uses these various methods to affect the motion of objects (animation).

a) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Expect entities to move continuously and just specify the changes in motion.

Example:If there is something in the way, stop.

b) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Continuously update the positions of entities.

Example:For each time around, if there is nothing in the way, move forward a little bit.

c) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Other (please specify) ____________________

8. Please count the number of times you see these various methods of expressing changes to an entity.

a) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Having behaviors built-into the entities. (object-oriented)

Example:Tell the robot to become happy.

b) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Directly modify the properties of entities.

Example:Set the robot’s emotion to ‘happy’.

c) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Other (please specify) ____________________

9. Please count the number of times the student uses these mathematical operations.

Consider when he/she is asked to increase/decrease a variable “count” by some units.

a) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

A more natural language style, but either the amount or variable is implicit (not mentioned)

Example:get points

b) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

A more natural language style, with both explicit variable and amount.

Example:ADD 20 units to count

count increases by 20 units

c) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Programming language style

Example:count = count + 20

d) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Mathematical style

Example:count + 20

e) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Other (please specify) ____________________

10. Please count the number of times the student uses these various methods to track progression a long task (suppose the student was assigned five books to read over the summer).

a) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Counting

Example:I will be happy when I have read 5 books

b) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

All or nothing

Example:I will be happy when I ......

..... have read the last book.

..... have read all of the books.

..... have no more books to read.

c) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Other (please specify) ____________________

11. Please count the number of times the student uses these various methods to express events that happen at an uncertain time or duration. (Problem #1 and #7)

a) 1______ 7______

He/she uses the word “random.”

Example:A flock of bird flies over the tree at random times.

b) 1______ 7______

He/she uses some other words to express a randomness concept.

Example:A flock of birds flies over the tree once in a while, occasionally, etc.

c) 1______ 7______

He/she specifies these things with exactness.

Example:A flock of birds flies over the tree every 3 hours.

c) 1______ 7______

He/she tries to specify the amount of duration, but NOT very exact.

Example:A flock of birds files over the tree about every 3 hours.

d) 1______ 7______

Other (please specify) ____________________

12. Please count the number of times the student uses the word “AND” in these various ways.

a) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Used as a sequencing word. (meaning “next”, “afterwards”)

Example:He knocked on the door and went in.

b) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Used to mean “as well as.” (boolean conjunction)

Example:We were cold and hungry.

c) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Other (please specify) ____________________

13. Please count the number of times the student uses the word “OR” in these various ways.

a) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Used as a boolean disjunction, or used in a set of possibilities.

Example:If it rains or it snows, I will wear my boots.

Would you prefer coffee, cocoa, or tea?

b) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Used to mean “otherwise”.

Example:Wear your coat or (else) you’ll be cold.

c) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Used when giving a second name or clarification for something.

Example:He was born in Saigon, or Ho Chi Minh City as it is now called.

d) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Other (please specify) ____________________

14. Please count the number of times the student uses the word “THEN” in these various ways.

a) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Used as a sequencing word. (meaning “next”, “afterwards”)

Example: Dinner was followed by coffee, then came the speeches.

b) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Used to mean “in that case” or “consequently”

Example:If you want to go home, then finish this work and go.

If x=5 and y=3, then x+y = 8.

c) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Used to mean “besides” or “also”

Example:You must ask Jill to the party, and then there’s Jane -- don’t forget her.

d) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Other (please specify) ____________________

15. Please count the number of times the student uses these various methods when inserting an element into the middle of an existing sequence of elements. (Problem #1 and #9)

a) 1______ 9______

Make room and then insert the element.

b) 1______ 9______

Insert the element and then push elements out of the way to make room.

c) 1______ 9______

Do not mention anything about making room for the new element.

d) 1______ 9______

Other (please specify) ____________________

16. Please count the number of times the student used any of these various methods to determine the right place for insertion. (Problem #1 and #9)

a) 1______ 9______

A correct general method that would work for any data (checks the items above and below).

b) 1______ 9______

A correct method that would only work for the example data (checks the items above and below).

c) 1______ 9______

Incorrect method, with missing or incorrect details.

d) 1______ 9______

Other (please specify) ____________________

17. Please count the number of times you see these various methods when a previous action in the past is supposed to affect a later action, how the previous state is remembered.

a) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Used the word “AFTER”.

Example:After installing snow tires, if it snows, you can drive more safely.

b) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Used the past tense mentioning the first event.

Example:If snow tires were installed, and it snows, you can drive more safely.

c) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Used the present tense mentioning the first event.

Example:If snow tires are installed, and it snows, you can drive more safely.

d) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Used something else that remembers the state, that is still true when the second event happens.

Example:If tires on your wheels are snow tires, and it snows, you can drive more safely.

e) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Used the future tense on the first event.

Example:If snow tires are installed, then next time it snows, you can drive more safely.

f) 1______ 2______ 3______ 4______ 5______ 6______ 7______ 8______ 9______

Other (please specify) ____________________

Is there any other observations you would like to make that were not covered by any of the questions? Please write them in the space below.

____

____

____

____

____

APPENDIX E

Materials from Study 2

The following pages contain the materials presented to the participants in Study Two. There are two versions of these materials, containing the identical set of questions presented in two different orders. This is followed by the rating form given to the analysts. The three raters for this study also were raters in Study 1. They did not get a new instruction sheet for this study, since they were already familiar with the rating task.

n

ID # ____________

- **We are trying to design a new programming language, a new way to program computers, and we want to find out how people would like to tell computer what to do.**

- **You are one of the best 'PlayStation' producer team. Now, you are launching the brand new "Mumbo Jumbo" game. So, your team decided to host a summer camp conducting a user testing with several groups of subjects.**
- **Your group consists of 10 quite-famous people, such as Bill Gates, Michael Jordan, etc.**
- **After you explain and demonstrate how the game works, you let them try. You, the expert, will give them advice and tricks.**
- **The score for each round of game playing is to be recorded. Your task is to tell the computer how to keep track of all the scores for each person to see how well they do.**

- **Now…Getting start with your task…**

- **Supposed you start off with this table, with all the names of members in your group:**

No.	First name	Last name	Round 1	Round 2	Round 3
1	Sandra	Bullock	0	0	0
2	Bill	Clinton	0	0	0
3	Cindy	Crawford	0	0	0
4	Tom	Cruise	0	0	0
5	Bill	Gates	0	0	0
6	Whitney	Houston	0	0	0
7	Michael	Jordan	0	0	0
8	Jay	Leno	0	0	0
9	David	Letterman	0	0	0
10	Will	Smith	0	0	0

- **Each person will report their 3 sets of score to you at different times.**
- **Whitney Houston comes in with the scores of 90,000 60,000 and 40,000:**
- **You do this:**

No.	First name	Last name	Round 1	Round 2	Round 3
1	Sandra	Bullock	0	0	0
2	Bill	Clinton	0	0	0
3	Cindy	Crawford	0	0	0
4	Tom	Cruise	0	0	0
5	Bill	Gates	0	0	0
6	Whitney	Houston	90,000	60,000	40,000
7	Michael	Jordan	0	0	0
8	Jay	Leno	0	0	0
9	David	Letterman	0	0	0
10	Will	Smith	0	0	0

- **Bill Clinton comes in with the scores of 40,000 60,000 and 60,000:**
- **You do this:**

No.	First name	Last name	Round 1	Round 2	Round 3
1	Sandra	Bullock	0	0	0
2	Bill	Clinton	40,000	60,000	60,000
3	Cindy	Crawford	0	0	0
4	Tom	Cruise	0	0	0
5	Bill	Gates	0	0	0
6	Whitney	Houston	90,000	60,000	40,000
7	Michael	Jordan	0	0	0
8	Jay	Leno	0	0	0
9	David	Letterman	0	0	0
10	Will	Smith	0	0	0

Continue on the next page...

- **David Letterman comes in with the scores of 70,000 30,000 and 80,000:**
- **You do this:**

No.	First name	Last name	Round 1	Round 2	Round 3
1	Sandra	Bullock	0	0	0
2	Bill	Clinton	40,000	60,000	60,000
3	Cindy	Crawford	0	0	0
4	Tom	Cruise	0	0	0
5	Bill	Gates	0	0	0
6	Whitney	Houston	90,000	60,000	40,000
7	Michael	Jordan	0	0	0
8	Jay	Leno	0	0	0
9	David	Letterman	70,000	30,000	80,000
10	Will	Smith	0	0	0

- **And so on….**
- **And finally at the end, you have this display.**

No.	First name	Last name	Round 1	Round 2	Round 3
1	Sandra	Bullock	10,000	50,000	20,000
2	Bill	Clinton	40,000	60,000	60,000
3	Cindy	Crawford	30,000	40,000	70,000
4	Tom	Cruise	30,000	50,000	70,000
5	Bill	Gates	40,000	90,000	60,000
6	Whitney	Houston	90,000	60,000	40,000
7	Michael	Jordan	90,000	10,000	40,000
8	Jay	Leno	80,000	20,000	40,000
9	David	Letterman	70,000	30,000	80,000
10	Will	Smith	20,000	40,000	80,000

Question 1:

- **Describe in detail what you would tell the computer to do to handle the situation above, so that each person's scores are put in at the right place and at the right time.**

- **Here is the recorded scores after 3 rounds of game playing, according to the alphabetical order of last name.**

No.	First name	Last name	Round 1	Round 2	Round 3
1	Sandra	Bullock	10,000	50,000	20,000
2	Bill	Clinton	40,000	60,000	60,000
3	Cindy	Crawford	30,000	40,000	70,000
4	Tom	Cruise	30,000	50,000	70,000
5	Bill	Gates	40,000	90,000	60,000
6	Whitney	Houston	90,000	60,000	40,000
7	Michael	Jordan	90,000	10,000	40,000
8	Jay	Leno	80,000	20,000	40,000
9	David	Letterman	70,000	30,000	80,000
10	Will	Smith	20,000	40,000	80,000

Question 2A

- **Describe in detail what you would tell the computer to do to get to these displays.**

No.	First name	Last name	Round 1	Round 2	Round 3	
1	Sandra	Bullock	10,000	50,000	20,000	**80,000**
2	Bill	Clinton	40,000	60,000	60,000	**160,000**
3	Cindy	Crawford	30,000	40,000	70,000	**140,000**
4	Tom	Cruise	30,000	50,000	70,000	**150,000**
5	Bill	Gates	40,000	90,000	60,000	**190,000**
6	Whitney	Houston	30,000	60,000	40,000	**130,000**
7	Michael	Jordan	10,000	10,000	40,000	**60,000**
8	Jay	Leno	80,000	20,000	40,000	**140,000**
9	David	Letterman	70,000	30,000	80,000	**180,000**
10	Will	Smith	20,000	80,000	10,000	**110,000**

Question 2B

- **Does your answer also work in this table below? If not, could you come up with another answer that really works for both tables?**

No.	First name	Last name	Round 1	Round 2	Round 3	Round 4	Round 5	
1	Leonardo	DiCaprio	10,000	50,000	20,000	20,000	10,000	**110,000**
2	Helen	Hunt	40,000	60,000	60,000	10,000	30,000	**200,000**
3	Jack	Nicholson	30,000	40,000	70,000	40,000	10,000	**190,000**
4	Brad	Pitt	70,000	30,000	80,000	20,000	10,000	**210,000**
5	Kate	Winslet	20,000	80,000	10,000	40,000	30,000	**180,000**

No.	First name	Last name	Round 4	Round 5	Round 6
1	Sandra	Bullock	40,000	300	20,000
2	Bill	Clinton	400	60,000	60,000
3	Cindy	Crawford	30,000	400	70,000
4	Tom	Cruise	30,000	3,000	70,000
5	Bill	Gates	40,000	90,000	600
6	Whitney	Houston	30,000	60,000	200
7	Michael	Jordan	10,000	10,000	1,200
8	Jay	Leno	80,000	20,000	4,000
9	David	Letterman	70,000	300	80,000
10	Will	Smith	20,000	800	10,000

Question 3

- **Describe in detail what you would tell the computer to do to obtain these results.**

No.	First name	Last name	Round 4	Round 5	Round 6	
1	Sandra	Bullock	40,000	~~300~~	20,000	**60,000**
2	Bill	Clinton	~~400~~	60,000	60,000	**120,000**
3	Cindy	Crawford	30,000	~~400~~	70,000	**100,000**
4	Tom	Cruise	30,000	~~3,000~~	50,000	**80,000**
5	Bill	Gates	40,000	100,000	~~600~~	**140,000**
6	Whitney	Houston	30,000	10,000	~~200~~	**40,000**
7	Michael	Jordan	10,000	10,000	~~1,200~~	**20,000**
8	Jay	Leno	80,000	20,000	~~4,000~~	**100,000**
9	David	Letterman	70,000	~~300~~	90,000	**160,000**
10	Will	Smith	100,000	~~800~~	80,000	**180,000**

No.	**First name**	**Last name**	**Group**
1	Sandra	Bullock	
2	Bill	Clinton	
3	Cindy	Crawford	
4	Tom	Cruise	
5	Bill	Gates	
6	Whitney	Houston	
7	Michael	Jordan	
8	Jay	Leno	
9	David	Letterman	
10	Will	Smith	

Question 4

- **Describe in detail what the computer should do to fill in the last column.**

No.	**First name**	**Last name**	**Group**
1	Sandra	Bullock	**Gold**
2	Bill	Clinton	**Gold**
3	Cindy	Crawford	**Gold**
4	Tom	Cruise	**Gold**
5	Bill	Gates	**Black**
6	Whitney	Houston	**Gold**
7	Michael	Jordan	**Gold**
8	Jay	Leno	**Black**
9	David	Letterman	**Black**
10	Will	Smith	**Gold**

No.	First name	Last name	Average Score	Performance
1	Sandra	Bullock	**3,000**	
2	Bill	Clinton	**60,000**	
3	Cindy	Crawford	**500**	
4	Tom	Cruise	**5,000**	
5	Bill	Gates	**6,000**	
6	Whitney	Houston	**4,000**	
7	Michael	Jordan	**20,000**	
8	Jay	Leno	**50,000**	
9	David	Letterman	**700**	
10	Will	Smith	**9,000**	

Question 5A

- **Describe in detail what the computer should do to obtain these results.**

No.	First name	Last name	Average Score	Performance
1	Sandra	Bullock	**3,000**	**Fine**
2	Bill	Clinton	**60,000**	**Extraordinary**
3	Cindy	Crawford	**500**	**Poor**
4	Tom	Cruise	**5,000**	**Fine**
5	Bill	Gates	**6,000**	**Fine**
6	Whitney	Houston	**4,000**	**Fine**
7	Michael	Jordan	**20,000**	**Extraordinary**
8	Jay	Leno	**50,000**	**Extraordinary**
9	David	Letterman	**700**	**Poor**
10	Will	Smith	**9,000**	**Fine**

Question 5B

- **Please fill in the table below with the appropriate performance, based on your answer given for Question 5A. If your answer does not work for these scores, could you come up with the new answer for 5A that works for these scores and all others?**

No.	First name	Last name	Average Score	Performance
1	Leonardo	DiCaprio	999	
2	Helen	Hunt	3,000,000	
3	Jack	Nicholson	1,000	
4	Brad	Pitt	10,000	
5	Jerry	Seinfeld	0	
6	Kate	Winslet	1,001	

No.	First name	Last name	Round 1	Round 2	Round 3	Total Score
1	Sandra	Bullock	10,000	50,000	20,000	**80,000**
2	Bill	Clinton	40,000	60,000	60,000	**160,000**
3	Cindy	Crawford	30,000	40,000	70,000	**140,000**
4	Tom	Cruise	30,000	50,000	70,000	**150,000**
5	Bill	Gates	40,000	90,000	60,000	**190,000**
6	Whitney	Houston	30,000	60,000	40,000	**130,000**
7	Michael	Jordan	10,000	10,000	40,000	**60,000**
8	Jay	Leno	80,000	20,000	40,000	**140,000**
9	David	Letterman	70,000	30,000	80,000	**180,000**
10	Will	Smith	20,000	80,000	10,000	**110,000**

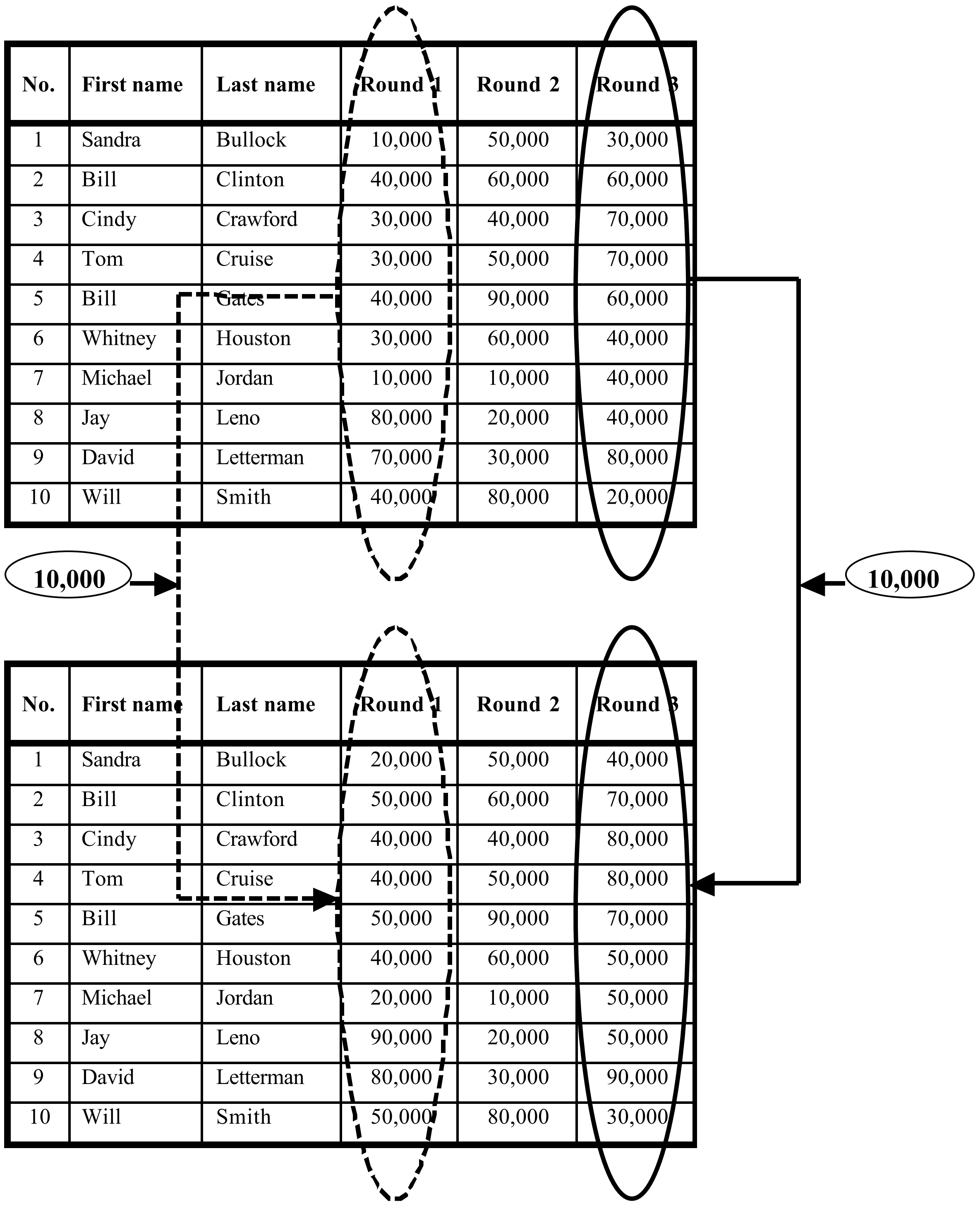
Question 6

- **Describe in detail what the computer should do to obtain these results. Also note the changes in the ordering.**

No.	First name	Last name	Total Score
1	Bill	Gates	190,000
2	David	Letterman	180,000
3	Bill	Clinton	160,000
4	Tom	Cruise	150,000

Question 7

- **There are mistakes in the recorded scores, i.e. scores from round 1 and round 3 were supposed to be 10,000 points higher.**
- **Describe in detail what needs to be done to correct the scores and obtain the new display.**



No.	First name	Last name	Round 1	Round 2	Round 3
1	Sandra	Bullock	10,000	50,000	30,000
2	Bill	Clinton	40,000	60,000	60,000
3	Cindy	Crawford	30,000	40,000	70,000
4	Tom	Cruise	30,000	50,000	70,000
5	Bill	Gates	40,000	90,000	60,000
6	Whitney	Houston	30,000	60,000	40,000
7	Michael	Jordan	10,000	10,000	40,000
8	Jay	Leno	80,000	20,000	40,000
9	David	Letterman	70,000	30,000	80,000
10	Will	Smith	40,000	80,000	20,000

No.	First name	Last name	Round 1	Round 2	Round 3
1	Sandra	Bullock	20,000	50,000	40,000
2	Bill	Clinton	50,000	60,000	70,000
3	Cindy	Crawford	40,000	40,000	80,000
4	Tom	Cruise	40,000	50,000	80,000
5	Bill	Gates	50,000	90,000	70,000
6	Whitney	Houston	40,000	60,000	50,000
7	Michael	Jordan	20,000	10,000	50,000
8	Jay	Leno	90,000	20,000	50,000
9	David	Letterman	80,000	30,000	90,000
10	Will	Smith	50,000	80,000	30,000

No.	First name	Last name	Round 1	Round 2	Round 3	Total
1	Sandra	Bullock	10,000	50,000	20,000	**80,000**
2	Bill	Clinton	40,000	60,000	60,000	**160,000**
3	Cindy	Crawford	30,000	40,000	70,000	**140,000**
4	Tom	Cruise	30,000	50,000	70,000	**150,000**
5	Bill	Gates	40,000	90,000	60,000	**190,000**
6	Whitney	Houston	30,000	60,000	40,000	**130,000**
7	Michael	Jordan	10,000	10,000	40,000	**60,000**
8	Jay	Leno	80,000	20,000	40,000	**140,000**
9	David	Letterman	70,000	30,000	80,000	**180,000**
10	Will	Smith	20,000	80,000	10,000	**110,000**

Question 8

- **"Bill Clinton" and "Jay Leno" need to leave the camp, but Elton John, instead, would like to join the camp.**
- **Describe in detail what the computer should do to obtain the new chart below.**

No.	First name	Last name	Round 1	Round 2	Round 3	
1	Sandra	Bullock	10,000	50,000	20,000	**80,000**
2	Cindy	Crawford	30,000	40,000	70,000	**140,000**
3	Tom	Cruise	30,000	50,000	70,000	**150,000**
4	Bill	Gates	40,000	90,000	60,000	**190,000**
5	Whitney	Houston	30,000	60,000	40,000	**130,000**
6	Elton	John	0	0	0	**0**
7	Michael	Jordan	10,000	10,000	40,000	**60,000**
8	David	Letterman	70,000	30,000	80,000	**180,000**
9	Will	Smith	20,000	80,000	10,000	**110,000**

No.	First name	Last name	Round 1	Round 2	Round 3	Round 4	Round 5	Round 6
1	Sandra	Bullock	5,000	8,000	2,000	4,000	1,000	100,000
2	Bill	Clinton	1,000	900,000	4,000	6,000	4,000	6,000
3	Cindy	Crawford	300,000	2,000	4,000	3,000	3,000	7,000
4	Tom	Cruise	5,000	7,000	1,000,000	3,000	3,000	2,000
5	Bill	Gates	400	1,000	3,000	4,000	900,000	600
6	Whitney	Houston	5,000	5,000	3,000	200,000	2,000	1,000
7	Michael	Jordan	2,000	7,000	350,000	2,000	1,000	3,000
8	Jay	Leno	2,000	3,000	3,000	800,000	2,000	4,000
9	David	Letterman	5,000	6,000	1,000	7,000	1,000	150,000
10	Will	Smith	4,000	2,000	3,000,000	2,000	9,000	1,000

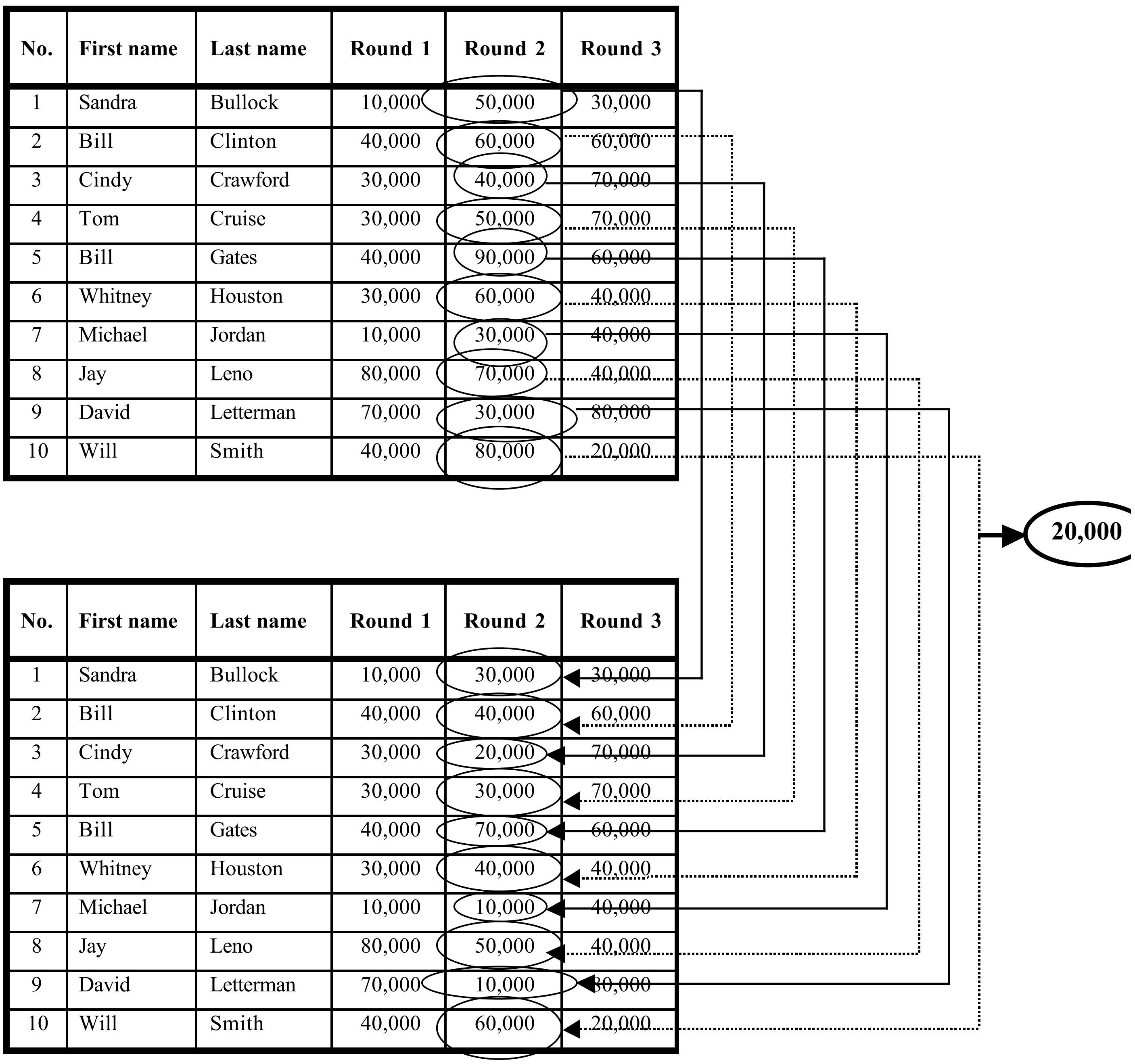
Question 9

- **Describe in detail what you would tell the computer to do to obtain these results.**

No.	First name	Last name	Round 1	Round 2	Round 3	Round 4	Round 5	Round 6	
1	Sandra	Bullock	5,000	8,000	2,000	4,000	1,000	100,000	**20,000**
2	Bill	Clinton	1,000	900,000	4,000	6,000	4,000	6,000	**21,000**
3	Cindy	Crawford	300,000	2,000	4,000	3,000	3,000	7,000	**19,000**
4	Tom	Cruise	5,000	7,000	1,000,000	3,000	3,000	2,000	**20,000**
5	Bill	Gates	400	1,000	3,000	4,000	900,000	600	**9,000**
6	Whitney	Houston	5,000	5,000	3,000	200,000	2,000	1,000	**16,000**
7	Michael	Jordan	2,000	7,000	350,000	2,000	1,000	3,000	**15,000**
8	Jay	Leno	2,000	3,000	3,000	800,000	2,000	4,000	**14,000**
9	David	Letterman	5,000	6,000	1,000	7,000	1,000	150,000	**20,000**
10	Will	Smith	4,000	2,000	3,000,000	2,000	9,000	1,000	**18,000**

Question 10

- **There is one more mistake in the recorded scores, i.e. scores from round 2 were supposed to be 20,000 points lower.**
- **Describe in detail what needs to be done to correct the scores and obtain the new display.**



No.	First name	Last name	Round 1	Round 2	Round 3
1	Sandra	Bullock	10,000	50,000	30,000
2	Bill	Clinton	40,000	60,000	60,000
3	Cindy	Crawford	30,000	40,000	70,000
4	Tom	Cruise	30,000	50,000	70,000
5	Bill	Gates	40,000	90,000	60,000
6	Whitney	Houston	30,000	60,000	40,000
7	Michael	Jordan	10,000	30,000	40,000
8	Jay	Leno	80,000	70,000	40,000
9	David	Letterman	70,000	30,000	80,000
10	Will	Smith	40,000	80,000	20,000

No.	First name	Last name	Round 1	Round 2	Round 3
1	Sandra	Bullock	10,000	30,000	30,000
2	Bill	Clinton	40,000	40,000	60,000
3	Cindy	Crawford	30,000	20,000	70,000
4	Tom	Cruise	30,000	30,000	70,000
5	Bill	Gates	40,000	70,000	60,000
6	Whitney	Houston	30,000	40,000	40,000
7	Michael	Jordan	10,000	10,000	40,000
8	Jay	Leno	80,000	50,000	40,000
9	David	Letterman	70,000	10,000	80,000
10	Will	Smith	40,000	60,000	20,000

No.	First name	Last name	Average Score
1	Sandra	Bullock	**3,000**
2	Bill	Clinton	**60,000**
3	Cindy	Crawford	**500**
4	Tom	Cruise	**5,000**
5	Bill	Gates	**6,000**
6	Whitney	Houston	**4,000**
7	Michael	Jordan	**20,000**
8	Jay	Leno	**50,000**
9	David	Letterman	**700**
10	Will	Smith	**9,000**

Question 11

- **Describe in detail what the computer should do to obtain these results.**

No.	First name	Last name	Average Score
1	Sandra	Bullock	**0**
2	Bill	Clinton	**0**
3	Cindy	Crawford	**0**
4	Tom	Cruise	**0**
5	Bill	Gates	**0**
6	Whitney	Houston	**0**
7	Michael	Jordan	**0**
8	Jay	Leno	**0**
9	David	Letterman	**0**
10	Will	Smith	**0**

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ID # ___________

- **We are trying to design a new programming language, a new way to program computers, and we want to find out how people would like to tell computer what to do.**

- **You are one of the best 'PlayStation' producer team. Now, you are launching the brand new "Mumbo Jumbo" game. So, your team decided to host a summer camp conducting a user testing with several groups of subjects.**
- **Your group consists of 10 quite-famous people, such as Bill Gates, Michael Jordan, etc.**
- **After you explain and demonstrate how the game works, you let them try. You, the expert, will give them advice and tricks.**
- **The score for each round of game playing is to be recorded. Your task is to tell the computer how to keep track of all the scores for each person to see how well they do.**

- **Now…Getting start with your task…**

- **Supposed you start off with this table, with all the names of members in your group:**

No.	First name	Last name	Round 1	Round 2	Round 3
1	Sandra	Bullock	0	0	0
2	Bill	Clinton	0	0	0
3	Cindy	Crawford	0	0	0
4	Tom	Cruise	0	0	0
5	Bill	Gates	0	0	0
6	Whitney	Houston	0	0	0
7	Michael	Jordan	0	0	0
8	Jay	Leno	0	0	0
9	David	Letterman	0	0	0
10	Will	Smith	0	0	0

- **Each person will report their 3 sets of score to you at different times.**
- **Whitney Houston comes in with the scores of 90,000 60,000 and 40,000:**
- **You do this:**

No.	First name	Last name	Round 1	Round 2	Round 3
1	Sandra	Bullock	0	0	0
2	Bill	Clinton	0	0	0
3	Cindy	Crawford	0	0	0
4	Tom	Cruise	0	0	0
5	Bill	Gates	0	0	0
6	Whitney	Houston	90,000	60,000	40,000
7	Michael	Jordan	0	0	0
8	Jay	Leno	0	0	0
9	David	Letterman	0	0	0
10	Will	Smith	0	0	0

- **Bill Clinton comes in with the scores of 40,000 60,000 and 60,000:**
- **You do this:**

No.	First name	Last name	Round 1	Round 2	Round 3
1	Sandra	Bullock	0	0	0
2	Bill	Clinton	40,000	60,000	60,000
3	Cindy	Crawford	0	0	0
4	Tom	Cruise	0	0	0
5	Bill	Gates	0	0	0
6	Whitney	Houston	90,000	60,000	40,000
7	Michael	Jordan	0	0	0
8	Jay	Leno	0	0	0
9	David	Letterman	0	0	0
10	Will	Smith	0	0	0

Continue on the next page...

- **David Letterman comes in with the scores of 70,000 30,000 and 80,000:**
- **You do this:**

No.	First name	Last name	Round 1	Round 2	Round 3
1	Sandra	Bullock	0	0	0
2	Bill	Clinton	40,000	60,000	60,000
3	Cindy	Crawford	0	0	0
4	Tom	Cruise	0	0	0
5	Bill	Gates	0	0	0
6	Whitney	Houston	90,000	60,000	40,000
7	Michael	Jordan	0	0	0
8	Jay	Leno	0	0	0
9	David	Letterman	70,000	30,000	80,000
10	Will	Smith	0	0	0

- **And so on….**
- **And finally at the end, you have this display.**

No.	First name	Last name	Round 1	Round 2	Round 3
1	Sandra	Bullock	10,000	50,000	20,000
2	Bill	Clinton	40,000	60,000	60,000
3	Cindy	Crawford	30,000	40,000	70,000
4	Tom	Cruise	30,000	50,000	70,000
5	Bill	Gates	40,000	90,000	60,000
6	Whitney	Houston	90,000	60,000	40,000
7	Michael	Jordan	90,000	10,000	40,000
8	Jay	Leno	80,000	20,000	40,000
9	David	Letterman	70,000	30,000	80,000
10	Will	Smith	20,000	40,000	80,000

Question 1:

- **Describe in detail what you would tell the computer to do to handle the situation above, so that each person’s scores are put in at the right place and at the right time.**

- **Here is the recorded scores after 3 rounds of game playing, according to the alphabetical order of last name.**

No.	First name	Last name	Round 1	Round 2	Round 3
1	Sandra	Bullock	10,000	50,000	20,000
2	Bill	Clinton	40,000	60,000	60,000
3	Cindy	Crawford	30,000	40,000	70,000
4	Tom	Cruise	30,000	50,000	70,000
5	Bill	Gates	40,000	90,000	60,000
6	Whitney	Houston	90,000	60,000	40,000
7	Michael	Jordan	90,000	10,000	40,000
8	Jay	Leno	80,000	20,000	40,000
9	David	Letterman	70,000	30,000	80,000
10	Will	Smith	20,000	40,000	80,000

Question 2A

- **Describe in detail what you would tell the computer to do to get to these displays.**

No.	First name	Last name	Round 1	Round 2	Round 3	
1	Sandra	Bullock	10,000	50,000	20,000	**80,000**
2	Bill	Clinton	40,000	60,000	60,000	**160,000**
3	Cindy	Crawford	30,000	40,000	70,000	**140,000**
4	Tom	Cruise	30,000	50,000	70,000	**150,000**
5	Bill	Gates	40,000	90,000	60,000	**190,000**
6	Whitney	Houston	30,000	60,000	40,000	**130,000**
7	Michael	Jordan	10,000	10,000	40,000	**60,000**
8	Jay	Leno	80,000	20,000	40,000	**140,000**
9	David	Letterman	70,000	30,000	80,000	**180,000**
10	Will	Smith	20,000	80,000	10,000	**110,000**

Question 2B

- **Does your answer also work in this table below? If not, could you come up with another answer that really works for both tables?**

No.	First name	Last name	Round 1	Round 2	Round 3	Round 4	Round 5	
1	Leonardo	DiCaprio	10,000	50,000	20,000	20,000	10,000	**110,000**
2	Helen	Hunt	40,000	60,000	60,000	10,000	30,000	**200,000**
3	Jack	Nicholson	30,000	40,000	70,000	40,000	10,000	**190,000**
4	Brad	Pitt	70,000	30,000	80,000	20,000	10,000	**210,000**
5	Kate	Winslet	20,000	80,000	10,000	40,000	30,000	**180,000**

No.	First name	Last name	Round 1	Round 2	Round 3	Round 4	Round 5	Round 6
1	Sandra	Bullock	5,000	8,000	2,000	4,000	1,000	100,000
2	Bill	Clinton	1,000	900,000	4,000	6,000	4,000	6,000
3	Cindy	Crawford	300,000	2,000	4,000	3,000	3,000	7,000
4	Tom	Cruise	5,000	7,000	1,000,000	3,000	3,000	2,000
5	Bill	Gates	400	1,000	3,000	4,000	900,000	600
6	Whitney	Houston	5,000	5,000	3,000	200,000	2,000	1,000
7	Michael	Jordan	2,000	7,000	350,000	2,000	1,000	3,000
8	Jay	Leno	2,000	3,000	3,000	800,000	2,000	4,000
9	David	Letterman	5,000	6,000	1,000	7,000	1,000	150,000
10	Will	Smith	4,000	2,000	3,000,000	2,000	9,000	1,000

Question 3

- **Describe in detail what you would tell the computer to do to obtain these results.**

No.	First name	Last name	Round 1	Round 2	Round 3	Round 4	Round 5	Round 6	
1	Sandra	Bullock	5,000	8,000	2,000	4,000	1,000	100,000	**20,000**
2	Bill	Clinton	1,000	900,000	4,000	6,000	4,000	6,000	**21,000**
3	Cindy	Crawford	300,000	2,000	4,000	3,000	3,000	7,000	**19,000**
4	Tom	Cruise	5,000	7,000	1,000,000	3,000	3,000	2,000	**20,000**
5	Bill	Gates	400	1,000	3,000	4,000	900,000	600	**9,000**
6	Whitney	Houston	5,000	5,000	3,000	200,000	2,000	1,000	**16,000**
7	Michael	Jordan	2,000	7,000	350,000	2,000	1,000	3,000	**15,000**
8	Jay	Leno	2,000	3,000	3,000	800,000	2,000	4,000	**14,000**
9	David	Letterman	5,000	6,000	1,000	7,000	1,000	150,000	**20,000**
10	Will	Smith	4,000	2,000	3,000,000	2,000	9,000	1,000	**18,000**

No.	First name	Last name	Group
1	Sandra	Bullock	
2	Bill	Clinton	
3	Cindy	Crawford	
4	Tom	Cruise	
5	Bill	Gates	
6	Whitney	Houston	
7	Michael	Jordan	
8	Jay	Leno	
9	David	Letterman	
10	Will	Smith	

Question 4

- **Describe in detail what the computer should do to fill in the last column.**

No.	First name	Last name	Group
1	Sandra	Bullock	**Gold**
2	Bill	Clinton	**Gold**
3	Cindy	Crawford	**Gold**
4	Tom	Cruise	**Gold**
5	Bill	Gates	**Black**
6	Whitney	Houston	**Gold**
7	Michael	Jordan	**Gold**
8	Jay	Leno	**Black**
9	David	Letterman	**Black**
10	Will	Smith	**Gold**

No.	First name	Last name	Average Score	Performance
1	Sandra	Bullock	**3,000**	
2	Bill	Clinton	**60,000**	
3	Cindy	Crawford	**500**	
4	Tom	Cruise	**5,000**	
5	Bill	Gates	**6,000**	
6	Whitney	Houston	**4,000**	
7	Michael	Jordan	**20,000**	
8	Jay	Leno	**50,000**	
9	David	Letterman	**700**	
10	Will	Smith	**9,000**	

Question 5A

- **Describe in detail what the computer should do to obtain these results.**

No.	First name	Last name	Average Score	Performance
1	Sandra	Bullock	**3,000**	**Fine**
2	Bill	Clinton	**60,000**	**Extraordinary**
3	Cindy	Crawford	**500**	**Poor**
4	Tom	Cruise	**5,000**	**Fine**
5	Bill	Gates	**6,000**	**Fine**
6	Whitney	Houston	**4,000**	**Fine**
7	Michael	Jordan	**20,000**	**Extraordinary**
8	Jay	Leno	**50,000**	**Extraordinary**
9	David	Letterman	**700**	**Poor**
10	Will	Smith	**9,000**	**Fine**

Question 5B

- **Please fill in the table below with the appropriate performances, based on your answer given for Question 5A. If your answer does not work for these scores, could you come up with the new answer for 5A that works for these scores and all others?**

No.	First name	Last name	Average Score	Performance
1	Leonardo	DiCaprio	999	
2	Helen	Hunt	3,000,000	
3	Jack	Nicholson	1,000	
4	Brad	Pitt	10,000	
5	Jerry	Seinfeld	0	
6	Kate	Winslet	1,001	

No.	First name	Last name	Round 1	Round 2	Round 3	Total Score
1	Sandra	Bullock	10,000	50,000	20,000	**80,000**
2	Bill	Clinton	40,000	60,000	60,000	**160,000**
3	Cindy	Crawford	30,000	40,000	70,000	**140,000**
4	Tom	Cruise	30,000	50,000	70,000	**150,000**
5	Bill	Gates	40,000	90,000	60,000	**190,000**
6	Whitney	Houston	30,000	60,000	40,000	**130,000**
7	Michael	Jordan	10,000	10,000	40,000	**60,000**
8	Jay	Leno	80,000	20,000	40,000	**140,000**
9	David	Letterman	70,000	30,000	80,000	**180,000**
10	Will	Smith	20,000	80,000	10,000	**110,000**

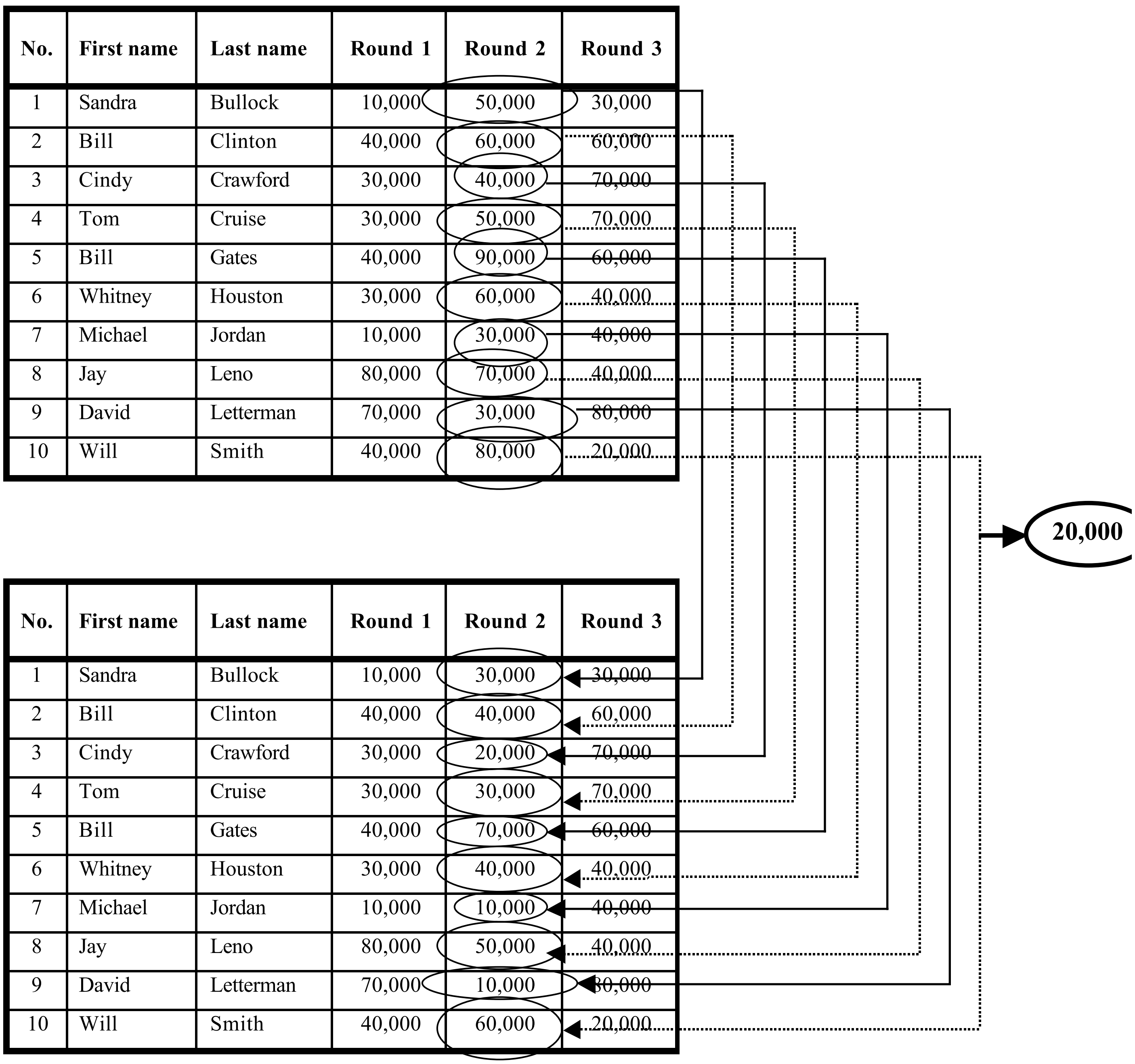
Question 6

- **Describe in detail what the computer should do to obtain these results. Also note the changes in the ordering.**

No.	First name	Last name	Total Score
1	Bill	Gates	190,000
2	David	Letterman	180,000
3	Bill	Clinton	160,000
4	Tom	Cruise	150,000

Question 7

- **There are some mistakes in the recorded scores, i.e. scores from round 2 were supposed to be 20,000 points lower.**
- **Describe in detail what needs to be done to correct the scores and obtain the new display.**



No.	First name	Last name	Round 1	Round 2	Round 3
1	Sandra	Bullock	10,000	50,000	30,000
2	Bill	Clinton	40,000	60,000	60,000
3	Cindy	Crawford	30,000	40,000	70,000
4	Tom	Cruise	30,000	50,000	70,000
5	Bill	Gates	40,000	90,000	60,000
6	Whitney	Houston	30,000	60,000	40,000
7	Michael	Jordan	10,000	30,000	40,000
8	Jay	Leno	80,000	70,000	40,000
9	David	Letterman	70,000	30,000	80,000
10	Will	Smith	40,000	80,000	20,000

No.	First name	Last name	Round 1	Round 2	Round 3
1	Sandra	Bullock	10,000	30,000	30,000
2	Bill	Clinton	40,000	40,000	60,000
3	Cindy	Crawford	30,000	20,000	70,000
4	Tom	Cruise	30,000	30,000	70,000
5	Bill	Gates	40,000	70,000	60,000
6	Whitney	Houston	30,000	40,000	40,000
7	Michael	Jordan	10,000	10,000	40,000
8	Jay	Leno	80,000	50,000	40,000
9	David	Letterman	70,000	10,000	80,000
10	Will	Smith	40,000	60,000	20,000

No.	First name	Last name	Round 1	Round 2	Round 3	Total
1	Sandra	Bullock	10,000	50,000	20,000	**80,000**
2	Bill	Clinton	40,000	60,000	60,000	**160,000**
3	Cindy	Crawford	30,000	40,000	70,000	**140,000**
4	Tom	Cruise	30,000	50,000	70,000	**150,000**
5	Bill	Gates	40,000	90,000	60,000	**190,000**
6	Whitney	Houston	30,000	60,000	40,000	**130,000**
7	Michael	Jordan	10,000	10,000	40,000	**60,000**
8	Jay	Leno	80,000	20,000	40,000	**140,000**
9	David	Letterman	70,000	30,000	80,000	**180,000**
10	Will	Smith	20,000	80,000	10,000	**110,000**

Question 8

- **"Bill Clinton" and "Jay Leno" need to leave the camp, but Elton John, instead, would like to join the camp.**
- **Describe in detail what the computer should do to obtain the new chart below.**

No.	First name	Last name	Round 1	Round 2	Round 3	
1	Sandra	Bullock	10,000	50,000	20,000	**80,000**
2	Cindy	Crawford	30,000	40,000	70,000	**140,000**
3	Tom	Cruise	30,000	50,000	70,000	**150,000**
4	Bill	Gates	40,000	90,000	60,000	**190,000**
5	Whitney	Houston	30,000	60,000	40,000	**130,000**
6	Elton	John	0	0	0	**0**
7	Michael	Jordan	10,000	10,000	40,000	**60,000**
8	David	Letterman	70,000	30,000	80,000	**180,000**
9	Will	Smith	20,000	80,000	10,000	**110,000**

No.	First name	Last name	Round 4	Round 5	Round 6
1	Sandra	Bullock	40,000	300	20,000
2	Bill	Clinton	400	60,000	60,000
3	Cindy	Crawford	30,000	400	70,000
4	Tom	Cruise	30,000	3,000	70,000
5	Bill	Gates	40,000	90,000	600
6	Whitney	Houston	30,000	60,000	200
7	Michael	Jordan	10,000	10,000	1,200
8	Jay	Leno	80,000	20,000	4,000
9	David	Letterman	70,000	300	80,000
10	Will	Smith	20,000	800	10,000

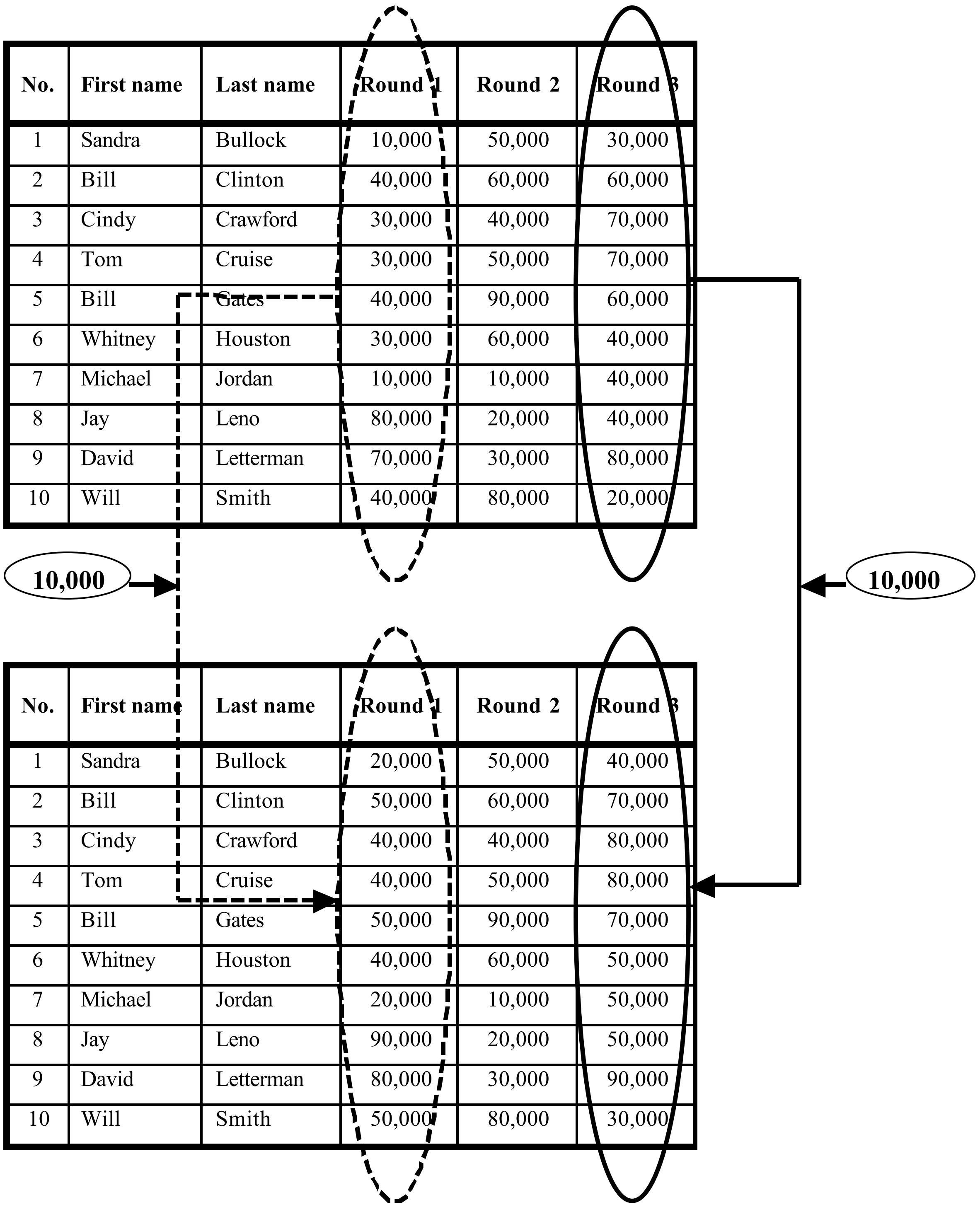
Question 9

- **Describe in detail what you would tell the computer to do to obtain these results.**

No.	First name	Last name	Round 4	Round 5	Round 6	
1	Sandra	Bullock	40,000	~~300~~	20,000	**60,000**
2	Bill	Clinton	~~400~~	60,000	60,000	**120,000**
3	Cindy	Crawford	30,000	~~400~~	70,000	**100,000**
4	Tom	Cruise	30,000	~~3,000~~	50,000	**80,000**
5	Bill	Gates	40,000	100,000	~~600~~	**140,000**
6	Whitney	Houston	30,000	10,000	~~200~~	**40,000**
7	Michael	Jordan	10,000	10,000	~~1,200~~	**20,000**
8	Jay	Leno	80,000	20,000	~~4,000~~	**100,000**
9	David	Letterman	70,000	~~300~~	90,000	**160,000**
10	Will	Smith	100,000	~~800~~	80,000	**180,000**

Question 10

- **There are two more mistakes in the recorded scores, i.e. scores from round 1 and round 3 were supposed to be 10,000 points higher.**
- **Describe in detail what needs to be done to correct the scores and obtain the new display.**



No.	First name	Last name	Round 1	Round 2	Round 3
1	Sandra	Bullock	10,000	50,000	30,000
2	Bill	Clinton	40,000	60,000	60,000
3	Cindy	Crawford	30,000	40,000	70,000
4	Tom	Cruise	30,000	50,000	70,000
5	Bill	Gates	40,000	90,000	60,000
6	Whitney	Houston	30,000	60,000	40,000
7	Michael	Jordan	10,000	10,000	40,000
8	Jay	Leno	80,000	20,000	40,000
9	David	Letterman	70,000	30,000	80,000
10	Will	Smith	40,000	80,000	20,000

No.	First name	Last name	Round 1	Round 2	Round 3
1	Sandra	Bullock	20,000	50,000	40,000
2	Bill	Clinton	50,000	60,000	70,000
3	Cindy	Crawford	40,000	40,000	80,000
4	Tom	Cruise	40,000	50,000	80,000
5	Bill	Gates	50,000	90,000	70,000
6	Whitney	Houston	40,000	60,000	50,000
7	Michael	Jordan	20,000	10,000	50,000
8	Jay	Leno	90,000	20,000	50,000
9	David	Letterman	80,000	30,000	90,000
10	Will	Smith	50,000	80,000	30,000

No.	First name	Last name	Average Score
1	Sandra	Bullock	**3,000**
2	Bill	Clinton	**60,000**
3	Cindy	Crawford	**500**
4	Tom	Cruise	**5,000**
5	Bill	Gates	**6,000**
6	Whitney	Houston	**4,000**
7	Michael	Jordan	**20,000**
8	Jay	Leno	**50,000**
9	David	Letterman	**700**
10	Will	Smith	**9,000**

Question 11

- **Describe in detail what the computer should do to obtain these results.**

No.	First name	Last name	Average Score
1	Sandra	Bullock	**0**
2	Bill	Clinton	**0**
3	Cindy	Crawford	**0**
4	Tom	Cruise	**0**
5	Bill	Gates	**0**
6	Whitney	Houston	**0**
7	Michael	Jordan	**0**
8	Jay	Leno	**0**
9	David	Letterman	**0**
10	Will	Smith	**0**

RATER'S NAME __________PARTICIPANT # _________FORM # ______

1. Please count the number of times the participant uses these various methods to express concepts about multiple objects.

a) 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ 7_____ 8_____ 9_____ 10_____ 11_____

Think of them as a set or subsets of entities and operate on those, specify them as plurals, or enumerating the members of the set. (please also answer the next question for each tick-mark.)

Example: Buy the books that are red.

Buy each of the books that is red.

For book1, book2, book3, ..., book15, if it is red, buy it.

b) 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ 7_____ 8_____ 9_____ 10_____ 11_____

Use an explicit for loop or other programming language form of iteration.

Example: For book1 to 15, if it is red, buy it.

If the book is red, buy it. Repeat 14 more times/Repeat until done.

c) 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ 7_____ 8_____ 9_____ 10_____ 11_____

Other (please specify) ____________________

2. When you found the use of Sets in Question 1-a (above), how did the participant construct those sets or subsets?

a) 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ 7_____ 8_____ 9_____ 10_____ 11_____

Using the word "ALL" or "for all"

Example: Buy all the books that are red.

b) 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ 7_____ 8_____ 9_____ 10_____ 11_____

Using the word "EACH" or "EVERY"

Example: For each book, if it is red, buy it.

Every book I bought today was red.

c) 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ 7_____ 8_____ 9_____ 10_____ 11_____

By enumerating the members of the set

Example: For book1, book2, book3, ..., book15, if it is red, buy it.

d) 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ 7_____ 8_____ 9_____ 10_____ 11_____

Using just plurals

Example: Buy the books that are red.

e) 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ 7_____ 8_____ 9_____ 10_____ 11_____

By naming the column of the database.

Example: Add 2,000 to ‘Round 1.’

f) 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ 7_____ 8_____ 9_____ 10_____ 11_____

Other (please specify) ____________________

3. In Questions 3, 4, and 9, please count the number of times the participant uses these various methods onsets or subsets after they have been created to handle conditions with various options.

a) 3_____ 4_____ 9_____

By using set difference.

Example: Throw away all those boxes except/but not the red one.

Throw away all those boxes. But if the box is red, keep it.

Add up all the numbers, except the highest.

b) 3_____ 4_____ 9_____

By specifying a subset, then make an inverse of that subset.

Example: Keep the red box, and throw away the rest/all others.

Delete the highest number, and add up all the rest.

c) 3_____ 4_____ 9_____

By specifying disjoint or mutually exclusive sets/subsets.

Example: Keep the red box. Throw away the boxes that are not red.

d) 3_____ 4_____ 9_____

Other (please specify) ____________________

4. Please count the number of times the participant uses an “IF” clause to handle conditions with various options.

a) 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ 7_____ 8_____ 9_____ 10_____ 11_____

By specifying mutually exclusive conditions.

Example: If the box is red, keep it. If the box is not red, throw it away.

b) 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ 7_____ 8_____ 9_____ 10_____ 11_____

By using nested conditions (the 2nd clause can stand alone but will give the wrong value.)

Example: If you score 90 or higher, you get an ‘A’. If you score 70 or higher, you get a ‘B’ (assuming that the score is also less than 90.)

c) 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ 7_____ 8_____ 9_____ 10_____ 11_____

By using an if clause with another dependent clause (the 2nd clause cannot stand alone.)

Example: If the box is red, keep it. Otherwise/Else/If not, throw it away.

If the box is red, keep it. If it is any other color, throw it away.

d) 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ 7_____ 8_____ 9_____ 10_____ 11_____

Other (please specify) ____________________

5. In Questions 5A and 5B (if any), did the answer cover every integer (were there any holes or overlaps)?

a) 5A_____ 5B_____

All numbers were covered, no holes and no overlaps.

b) 5A_____ 5B_____

Some numbers were NOT covered, or some overlaps occurred.

6. In Questions 5A and 5B (if any), how are the ranges specified to handle open intervals, typically for the ‘poor’ and ‘extraordinary’ performances?

a) 5A_____ 5B_____

Used a Mathematical Notation instead of words.

Example: “> 200”

“<= 100”

b) 5A_____ 5B_____

Used a word like “above”, “below”, “greater than”, “less than” to be EXCLUSIVE.

Example: “Above 200” means strictly greater than 200.

“200 or greater” so that the implied meaning is exclusive.

c) 5A_____ 5B_____

Used a word like “above”, “below”, “greater than”, “less than” to be INCLUSIVE.

Example: "Above 200" means greater than or equal to 200

d) 5A_____ 5B_____

Used power of ten to specify the range.

Example: "In the hundreds"

e) 5A_____ 5B_____

Other (please specify) ____________________

7. In Questions 5A and 5B (if any), how are the ranges specified to handle closed interval, typically for the 'fine' performance?

a) 5A_____ 5B_____

Used a Mathematical Notation instead of words.

Example: "100 < x < 200"

b) 5A_____ 5B_____

Used the word "between" to be EXCLUSIVE.

Example: "between 100 and 200" means 100 < x < 200

c) 5A_____ 5B_____

Used the word "between" to be INCLUSIVE.

Example: "between 100 and 200" means 100 <= x <= 200

d) 5A_____ 5B_____

Used the word "between", with inconsistent meaning on each end of interval

Example: "between 100 and 200" means 100 <= x < 200 or 100 < x <= 200

e) 5A_____ 5B_____

Used the word "from...to", a symbol "-", or something similar to be EXCLUSIVE.

Example: "from 100 to 200" or "100 - 200" means 100 < x < 200

f) 5A_____ 5B_____

Used the word "from...to", a symbol "-", or something similar to be INCLUSIVE.

Example: "from 100 to 200" or "100 - 200" means 100 <= x <= 200

g) 5A_____ 5B_____

Used the word "from...to", a symbol "-", or something similar, but had inconsistent meaning on each end of interval.

Example: "from 100 to 200" or "100 - 200" means 100 <= x < 200 or 100 < x <= 200

h) 5A_____ 5B_____

Specify each end of the interval.

Example: “greater than 100 and/but less than 200”

“greater than or equal to 100 and less than or equal to 200”

i) 5A_____ 5B_____

Used power of ten to specify the range

Example: “In the hundreds”

j) 5A_____ 5B_____

Other (please specify) _____________________

8. Please count the number of times the participant uses these mathematical operations.

Consider when he/she is asked to increase/decrease a variable “count” by some units.

a) 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ 7_____ 8_____ 9_____ 10_____ 11_____

A more natural language style, with explicit variable and amount.

Example: ADD 20 units to “count”

“count” increases by 20 units

b) 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ 7_____ 8_____ 9_____ 10_____ 11_____

Programming language style

Example: count = count + 20

c) 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ 7_____ 8_____ 9_____ 10_____ 11_____

Mathematical style

Example: count + 20

d) 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ 7_____ 8_____ 9_____ 10_____ 11_____

Other (please specify) _____________________

9. Please count the number of times the participant uses the word “BUT” in these various ways.

a) 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ 7_____ 8_____ 9_____ 10_____ 11_____

Used to mean “except”

Example: He threw away all those boxes but the red one.

b) 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ 7_____ 8_____ 9_____ 10_____ 11_____

Used to mean “AND”

Example: If the box is empty but is red, do not throw it away.

You will get a ‘B’ if you score above 80 but less than 90.

c) 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ 7_____ 8_____ 9_____ 10_____ 11_____

Other (please specify) ____________________

10. Please count the number of times the participant uses the word “AND” in these various ways.

a) 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ 7_____ 8_____ 9_____ 10_____ 11_____

Used as a sequencing word. (meaning “next”, “afterwards”)

Example: He knocked on the door and went in.

b) 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ 7_____ 8_____ 9_____ 10_____ 11_____

Used to mean “as well as.” (Boolean conjunction)

Example: We were cold and hungry.

c) 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ 7_____ 8_____ 9_____ 10_____ 11_____

Used for range specification.

Example: Select a number between 1 and 10.

d) 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ 7_____ 8_____ 9_____ 10_____ 11_____

Other (please specify) ____________________

11. In question 4 and possibly also in question 5, please count the number of times the participant uses “AND” as a Boolean expression correctly and incorrectly, in terms of how a programming language would use it.

a) 4_____ 5_____

If used, used it correctly.

Example: Extra credit is given if you turned in all the homework AND attended all the lectures.

b) 4_____ 5_____

Used it in a way that would not work in a programming language.

Example: You will get an 'A' if you score 90 AND above. (Scores cannot actually be 90 and above 90 at the same time.)

12. In question 4 and possibly also in question 5, please count the number of times the participant uses "OR" as a Boolean expression correctly and incorrectly, in terms of how a programming language would use it.

a) 4_____ 5_____

Used it correctly. (the implied parenthesis may be needed in case of 'NOT')

Example: "You will get an 'A' if you score 90 OR above."

"You will not get an 'A' if you do NOT score 90 OR above."

b) 4_____ 5_____

Used it in a way that would not work in a programming language.

13. In Question 4, if the participant used the word 'NOT', please count the number of times the participant expressed his/her concept about the precedent binding of "NOT" in these various ways.

a) 4_____

Low-precedence: "Not A or B" means Not(A or B)

Example: You will get a 'B' or a 'C' if you do NOT score 90 or higher.

b) 4_____

High-precedence: "Not A or B" means (Not A) or B

Example: You will get a 'B' if you do (NOT score higher than 90) and higher than 80.

c) 4_____

Other (please specify) ____________________

14. Please count the number of times the participant uses the word "THEN" in these various ways.

a) 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ 7_____ 8_____ 9_____ 10_____ 11_____

Used as a sequencing word (meaning "next", "afterwards")

Example: Dinner was followed by coffee, then came the speeches.

b) 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ 7_____ 8_____ 9_____ 10_____ 11_____

Used to mean “in that case” or “consequently”

Example: If you want to go home, then finish this work and go.

If x=5 and y=3, then x+y = 8.

c) 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ 7_____ 8_____ 9_____ 10_____ 11_____

Used to mean “besides” or “also”

Example: You must ask Jill to the party, and then there’s Jane -- don’t forget her.

d) 1_____ 2_____ 3_____ 4_____ 5_____ 6_____ 7_____ 8_____ 9_____ 10_____ 11_____

Other (please specify) ____________________

15. In Questions 6 and 8, how did the participant express concepts about Sorting?

a) 6_____ 8_____

Used words such as “ascending” or “descending” order.

b) 6_____ 8_____

Used keywords such as, “alphabetical” or “numerical” order.

c) 6_____ 8_____

Used generic words such as “from A to Z” or “from lowest to highest”

d) 6_____ 8_____

Specified the sort key, such as “according to lastname/score”

e) 6_____ 8_____

Used specific examples such as

“the first one is the highest, the second one is the second highest, and so on”

f) 6_____ 8_____

Other (please specify) ____________________

16. In Question 8 please count the number of times the participant uses these various methods when deleting an element out of an existing sequence of elements.

a) 8_____

Delete the element assuming there will be no hole after deletion.

b) 8_____

Delete the element assuming there will be a hole, then fix up the hole.

c) 8_____

Other (please specify) ____________________

17. In Question 8, please count the number of times the participant uses these various methods when inserting an element into an existing sequence of elements.

a) 8_____

Make room and then insert the element.

b) 8_____

Insert the element and then push other elements out of the way to make room.

c) 8_____

Insert the element without mentioning anything about making room.

d) 8_____

Other (please specify) ____________________

18. In Question 8, please count the number of times the participant used any of these various methods to determine the right place for insertion.

a) 8_____

Insert an element somewhere, and then sort the new sequence of elements.

b) 8_____

Insert an element, with a correct method, to the right place where it belongs, but in a way that only works with this specific data.

c) 8_____

Insert an element, with a correct method, to the right place where it belongs, that would also work for any data.

d) 8_____

Incorrect method, with missing or incorrect details.

e) 8_____

Other (please specify) ____________________

Are there any other observations you would like to make that were not covered by any of the questions? Please write them in the space below.

____

____

____

____

APPENDIX F Materials from Study 3

This following pages contain the materials from Study 3. Note that these materials appear in full color at:

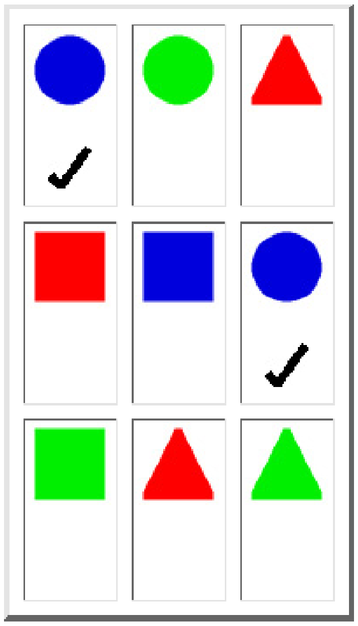
http://www.cs.cmu.edu/~pane/PaneThesis.pdf

Instructions:

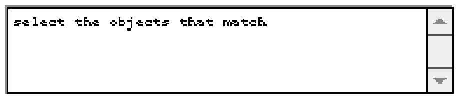
In this part of the survey, we will show you some pictures of nine objects with various shapes and colors. Some of the objects will have checkmarks. We want you to type in some words that describe exactly which objects have the checkmarks.

Try to write your description so that it picks **exactly** the checkmarked objects -- no more, no less. This can be a little tricky, so please check your answer to be sure that it is right.

Example 1:



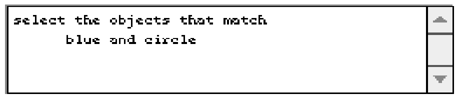
There will be a box that is partially filled in, like this:



```
select the objects that match
```

(if you don't like the words that are already filled in, you can change them)

You will type in an answer, like this:

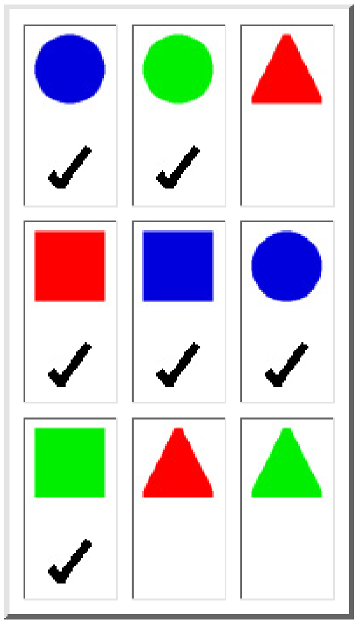


```
select the objects that match
      blue and circle
```

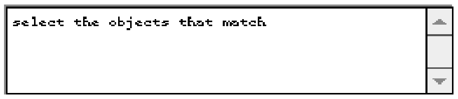
The blue circles are picked by this answer because they have both of the mentioned properties. Notice that the green circle and the blue square are not picked.

Example 2:

The word **NOT** can be used to specify the exclusion of a certain shape or color.

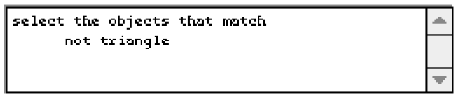


There will be a box that is partially filled in, like this:



```
select the objects that match
```

You will type in an answer, like this:

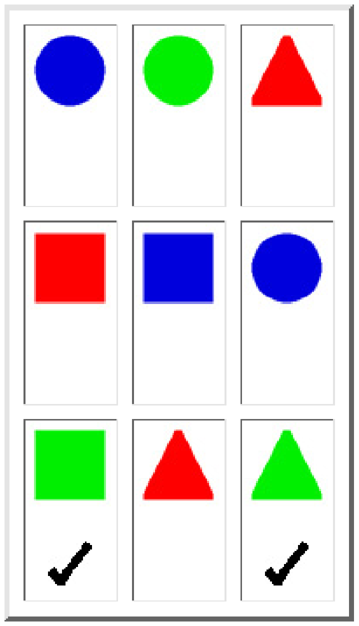


```
select the objects that match
      not triangle
```

Only the objects that are not triangles are picked by this answer.

Example 3:

The word **OR** can be used to include two kinds of objects. Parenthesis can be used to group the words to clarify which ones go together.



There will be a box that is partially filled in, like this:

```
select the objects that match
```

You will type in an answer, like this:

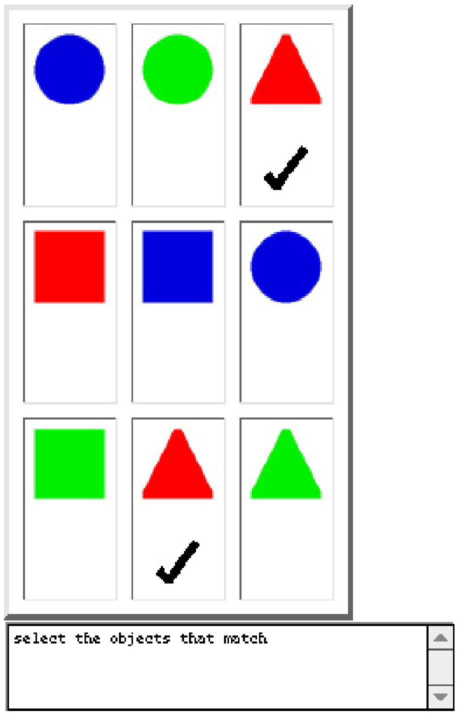
```
select the objects that match
      green and (triangle or square)
```

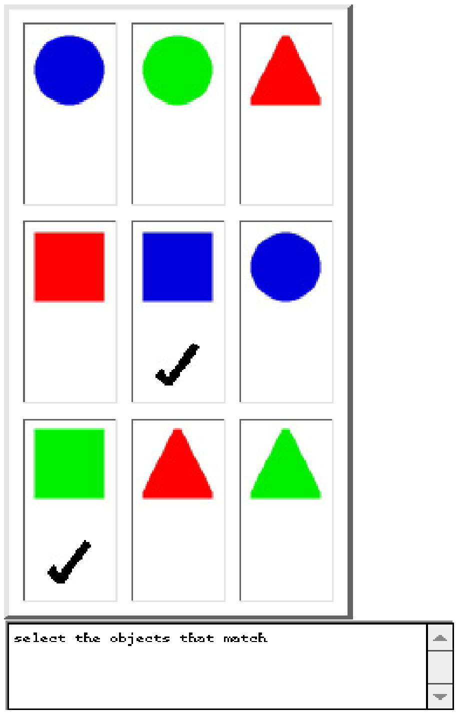
This answer includes triangles as well as squares, but only the ones that are green.

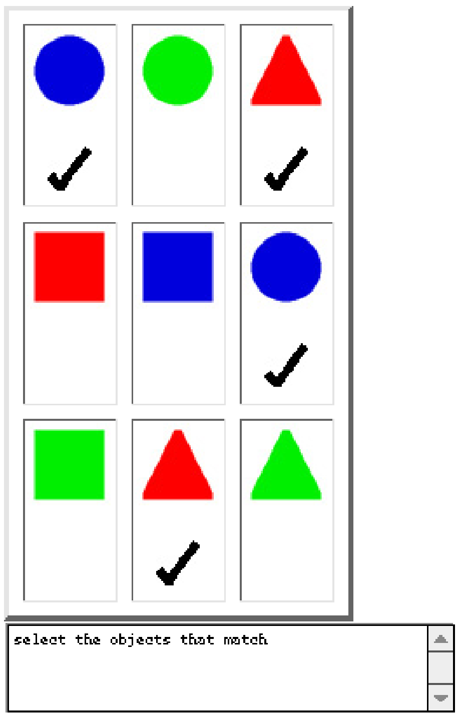
In your answer, you must separate a color word from a shape word. For example, instead of **blue circle,** you have to write **blue and circle** or any other phrase that has at least one word between the shape word and the color word.

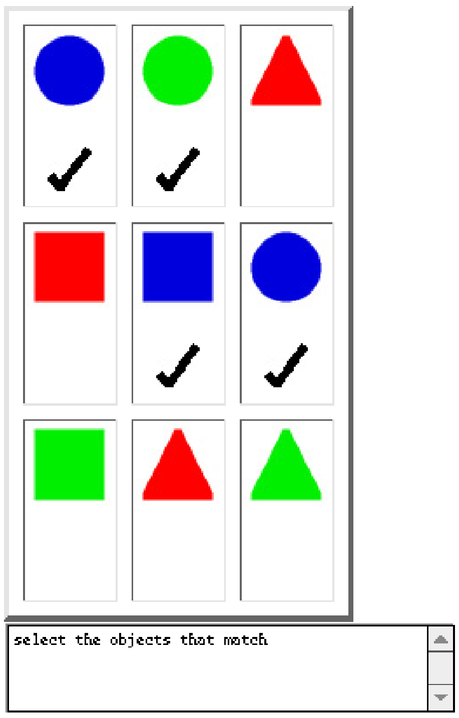
When you are ready to begin, please press the "Ready" button.

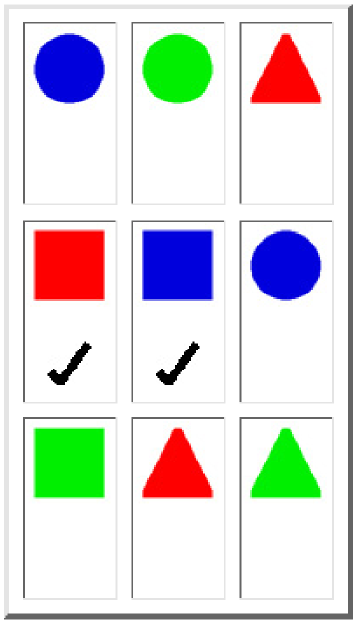
Ready


select the objects that match


select the objects that match


select the objects that match


select the objects that match



Please try to use the word NOT somewhere in your answer to this one.

select the objects that match

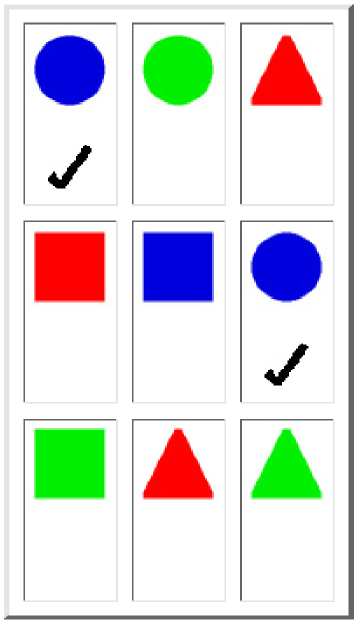
Instructions:

In this part of the survey, we will show you some pictures of nine objects with various shapes and colors. Some of the objects will have checkmarks. We want you to fill in **match forms** to describe exactly which objects have the checkmarks.

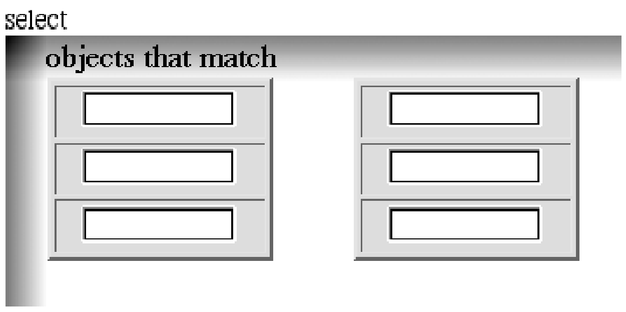
Try to fill in the **match forms** so that they pick **exactly** the checkmarked objects -- no more, no less. This can be a little tricky, so please check your answer to be sure that it is right.

For an object to get picked by a **match form,** all of the things mentioned on the **match form** must be true about the object. If two or more objects match, they are all picked.

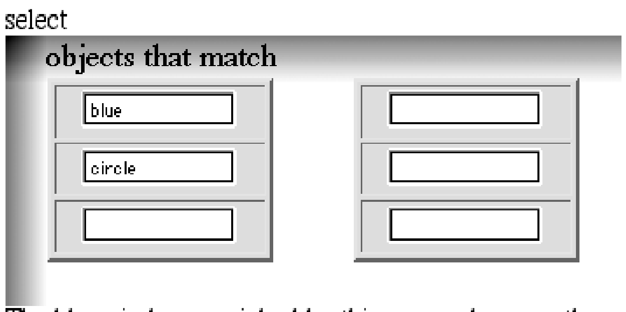
Example 1:



There will be two blank match forms.



You will fill in one or both match forms, like this:



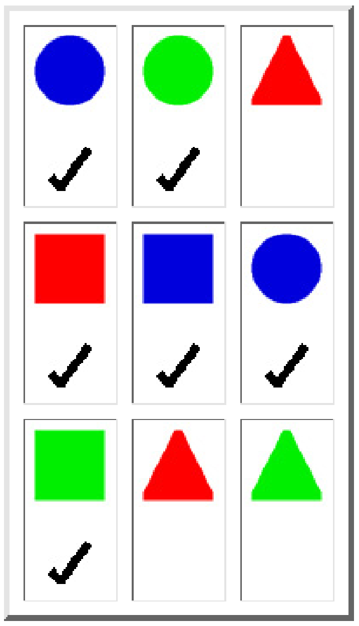
blue	
circle	

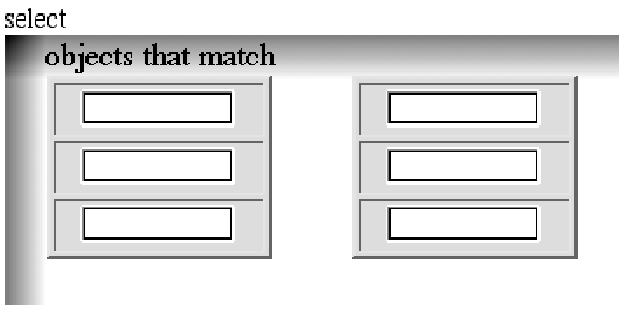
The blue circles are picked by this answer because they are the only objects that match all of the things mentioned on the **match card.** When the second match card isn't needed, it is left blank.

Example 2:

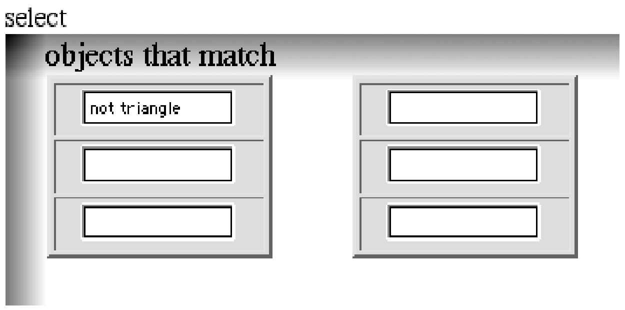
The word **NOT** can be used to specify the exclusion of a certain shape or color.

There will be two blank match forms.





You will fill in one or both match forms, like this:



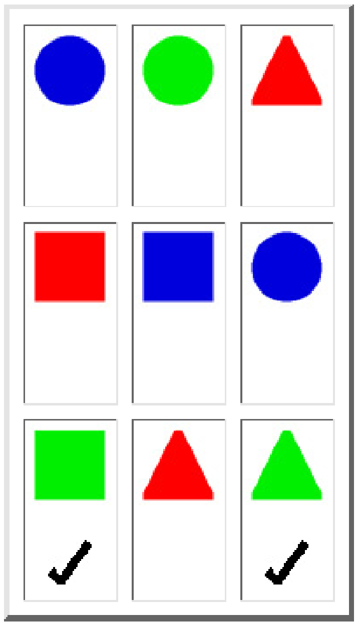
select
objects that match

not triangle

Only the objects that are not triangles are picked by this answer. Once again, the second **match form** is left blank because it isn't needed here.

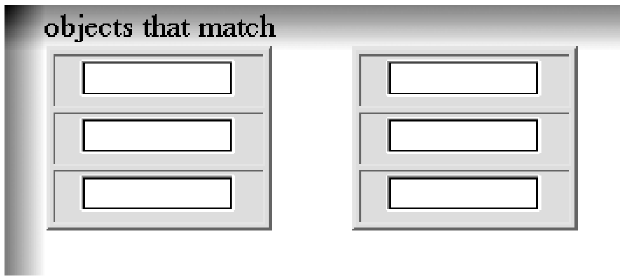
Example 3:

When both **match forms** are filled in, all of the objects that are picked by the first form are included, as well as all of the objects that are picked by the second form.



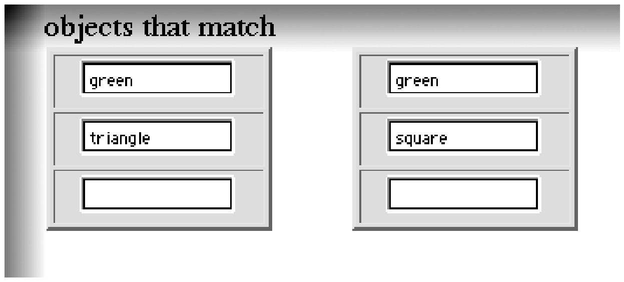
There will be two blank match forms.

select



You will fill in one or both match forms, like this:

select



green
triangle

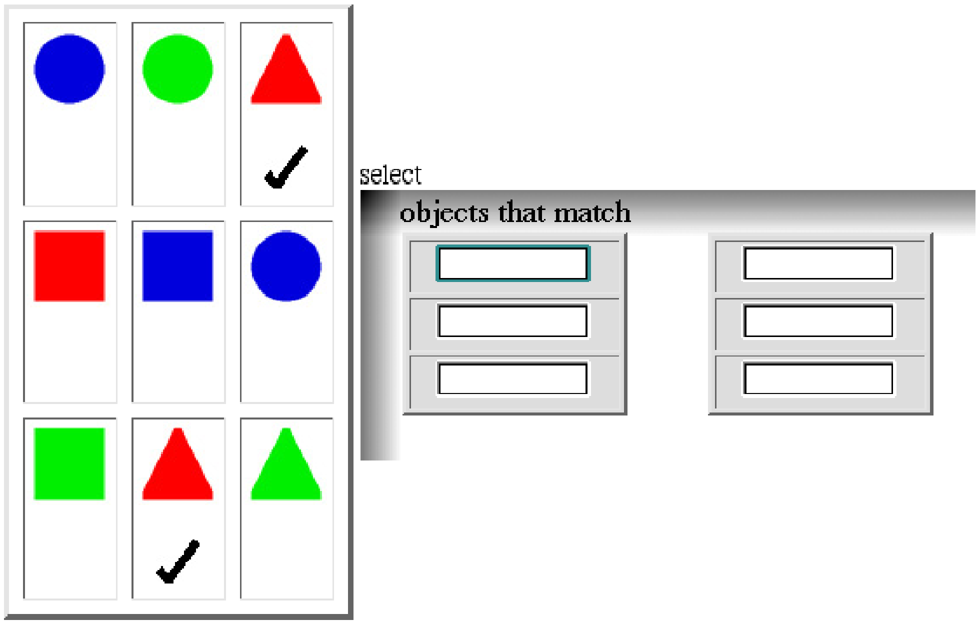
green
square

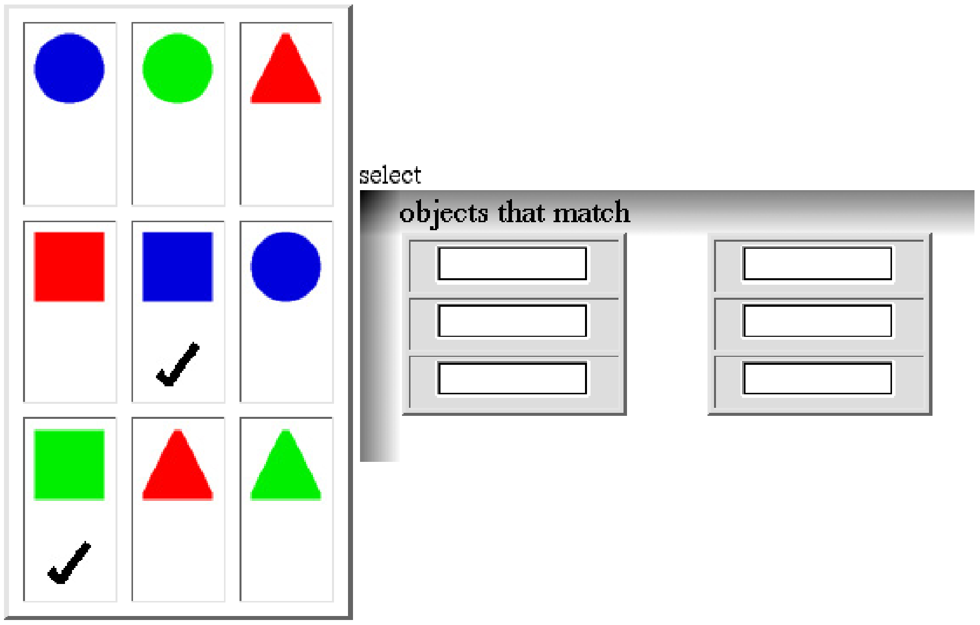
First, all of the green triangles are picked by first **match form**, then all of the green squares are picked by the second **match form**.

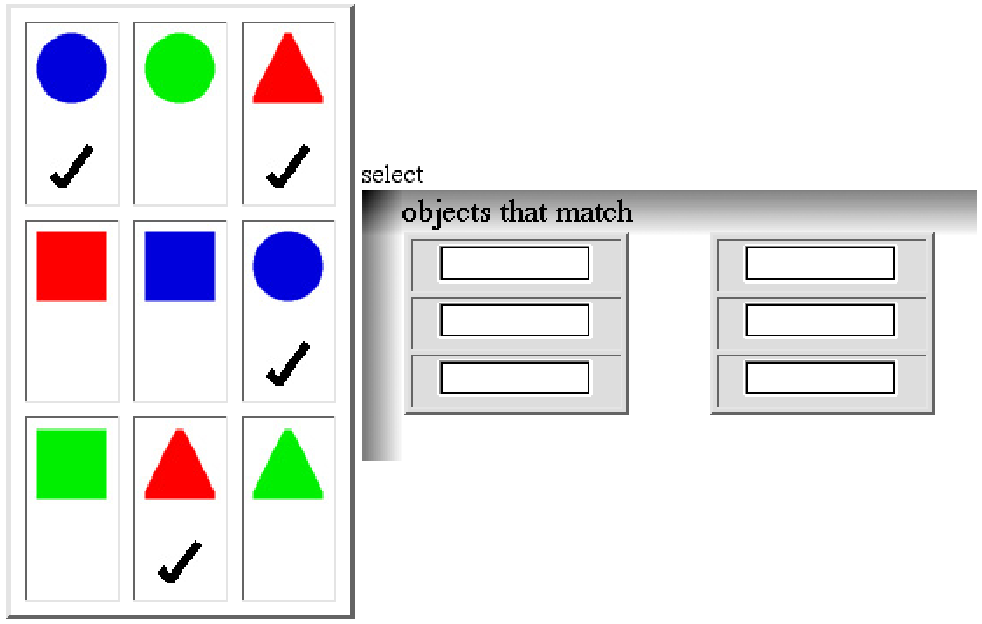
Each line of the **match form** should mention only a single shape or a single color. For example, instead of putting **blue circle** into a single line on the form, please put **blue** on one line and **circle** on another line.

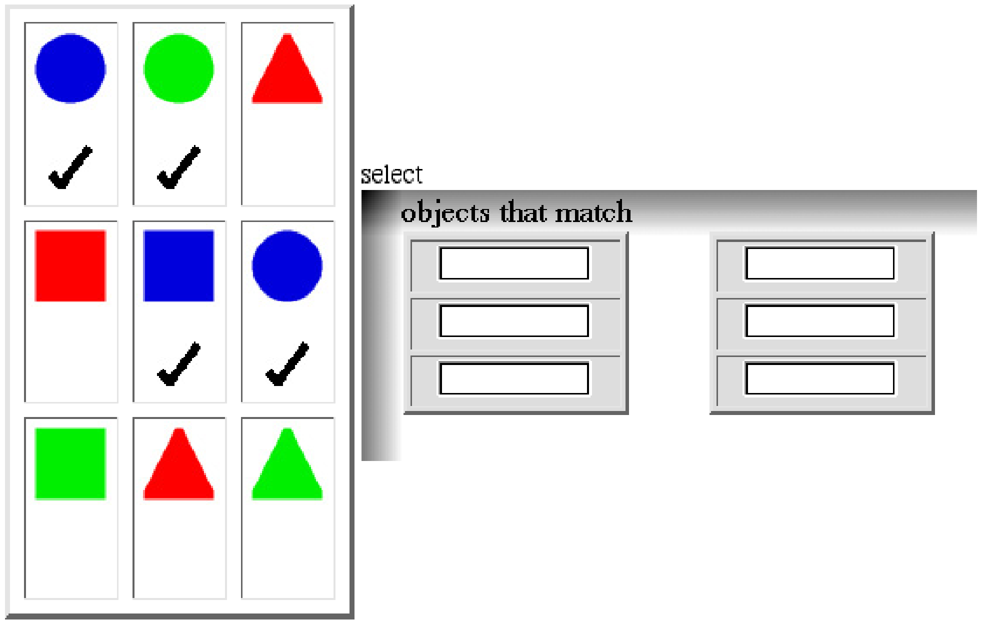
When you are ready to begin, please press the "Ready" button.

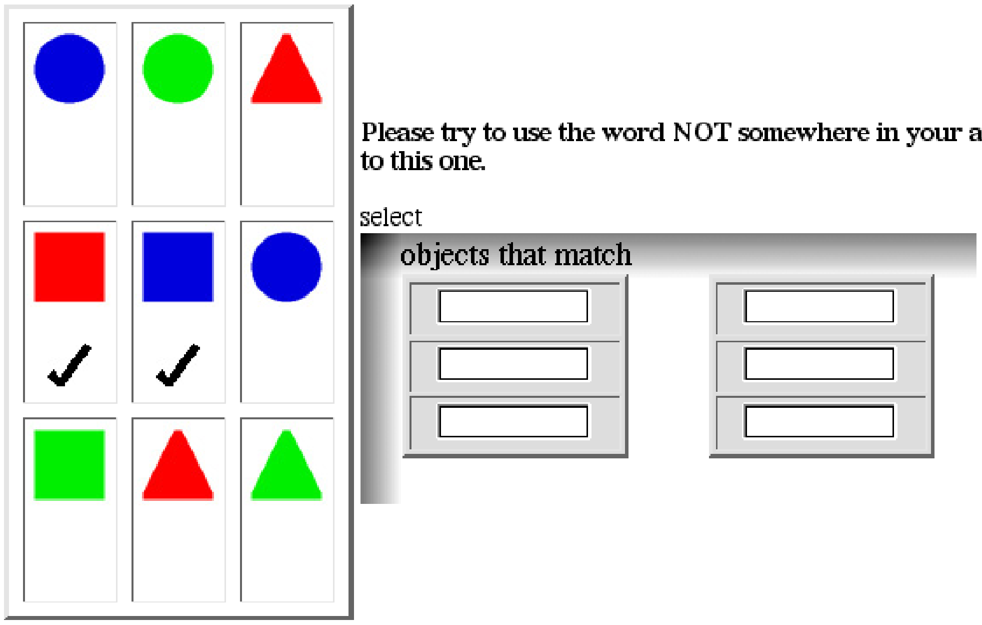
Ready


select
objects that match


select
objects that match


select
objects that match


select
objects that match



Please try to use the word NOT somewhere in your answer to this one.

Instructions:

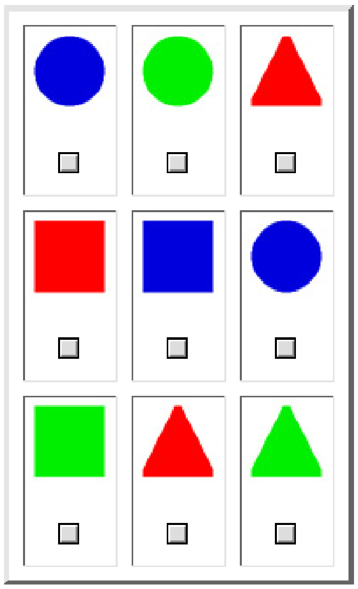
This next section of the survey goes back to using words to describe the objects. This time we will describe which objects should be picked from the group, and you will pick them.

Carefully consider **exactly** which objects we are describing, and mark them by clicking the boxes under them. This can be a little tricky, so please check your answer to be sure that it is right.

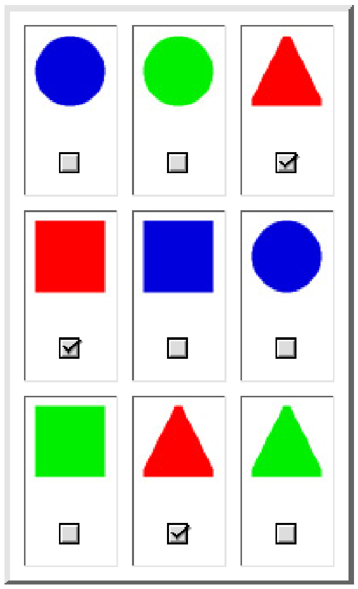
Example:

select the objects that match red

All of the objects will be start out unmarked, like this:



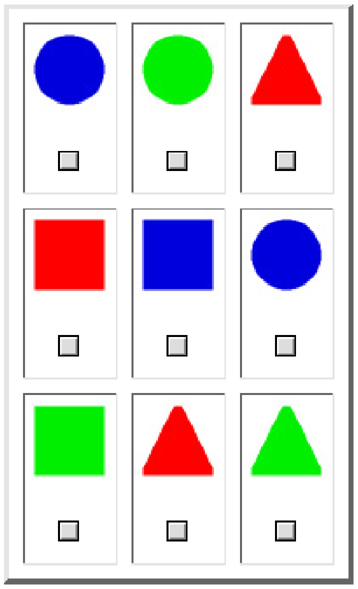
You will mark the objects that are described, like this:



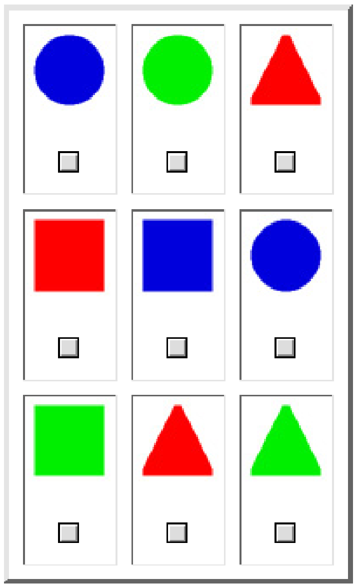
When you are ready to begin, please press the "Ready" button.

Ready

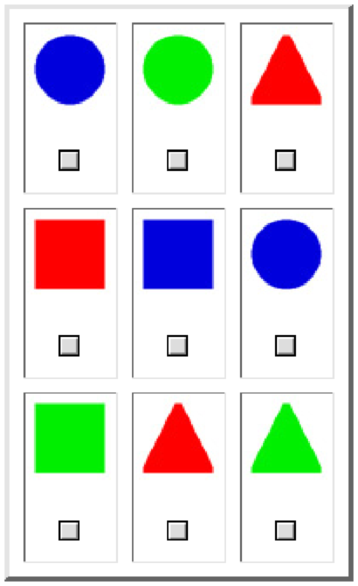
select the objects that match square or green



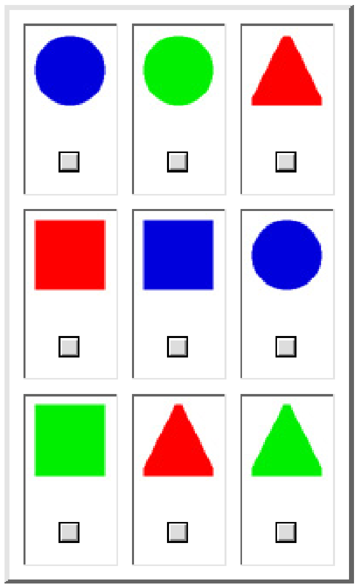
select the objects that match blue and the objects that match circle



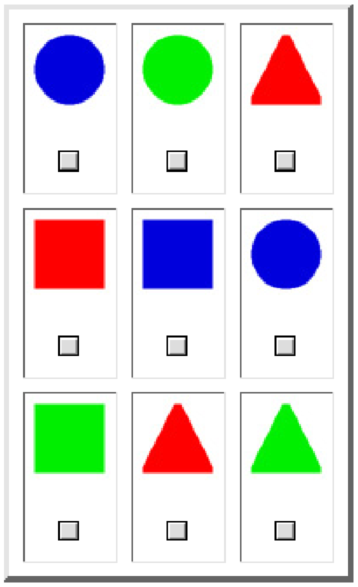
select the objects that match red, if the objects match triangle



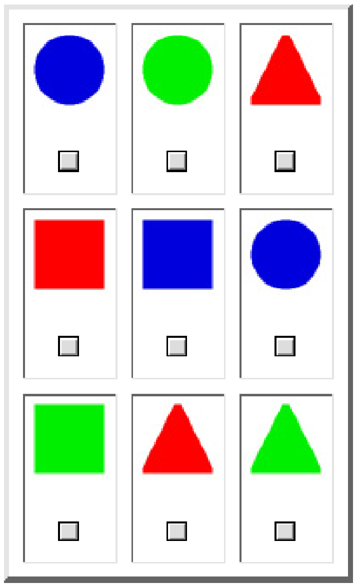
select the objects that match blue and circle



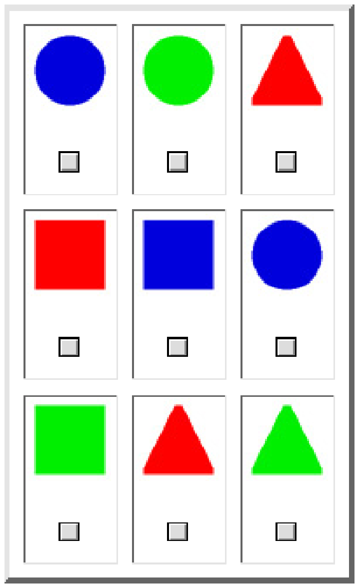
select the objects that match blue, unless the objects match square



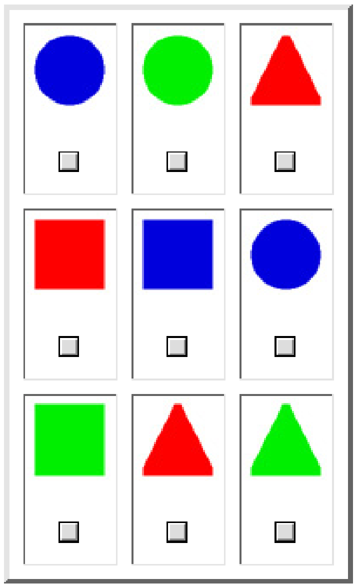
select the objects that match not red and square



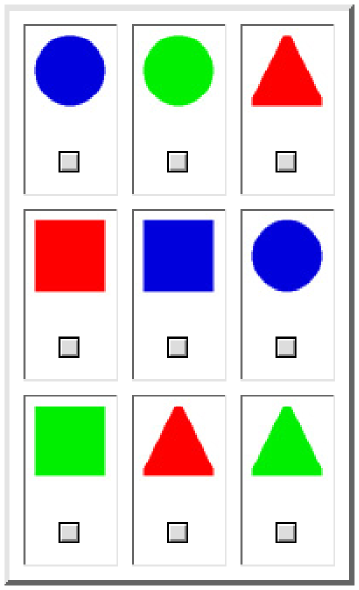
select the objects that match square and not red



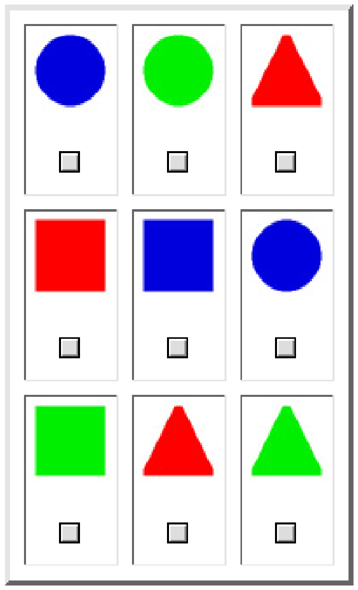
unless the objects match green, select the objects that match circle



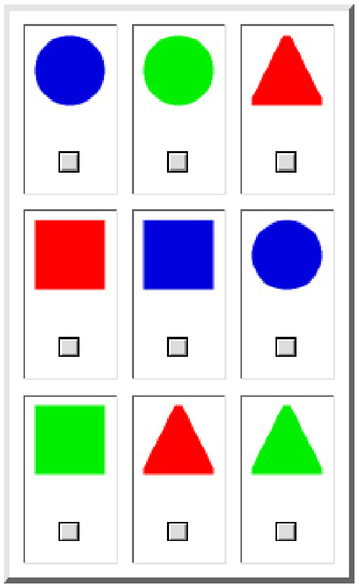
select the objects that match not (triangle or red)



select the objects that match (not circle) or blue



select the objects that match not triangle or green

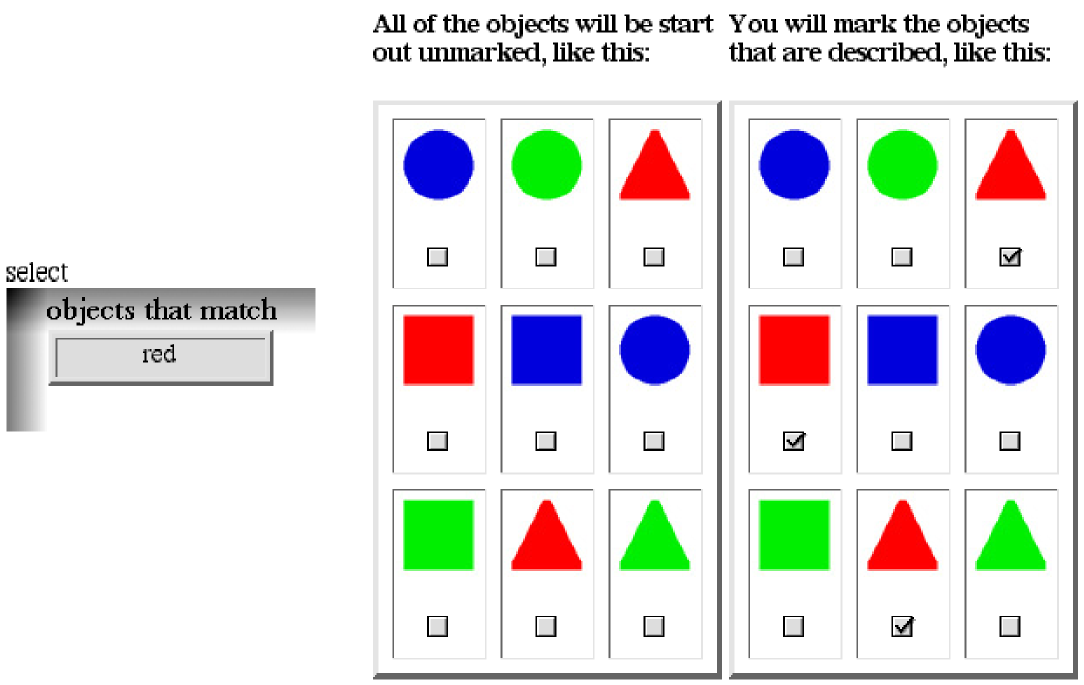


Instructions:

This next section of the survey goes back to using **match forms** to describe the objects. This time we will describe which objects should be picked from the group, and you will pick them.

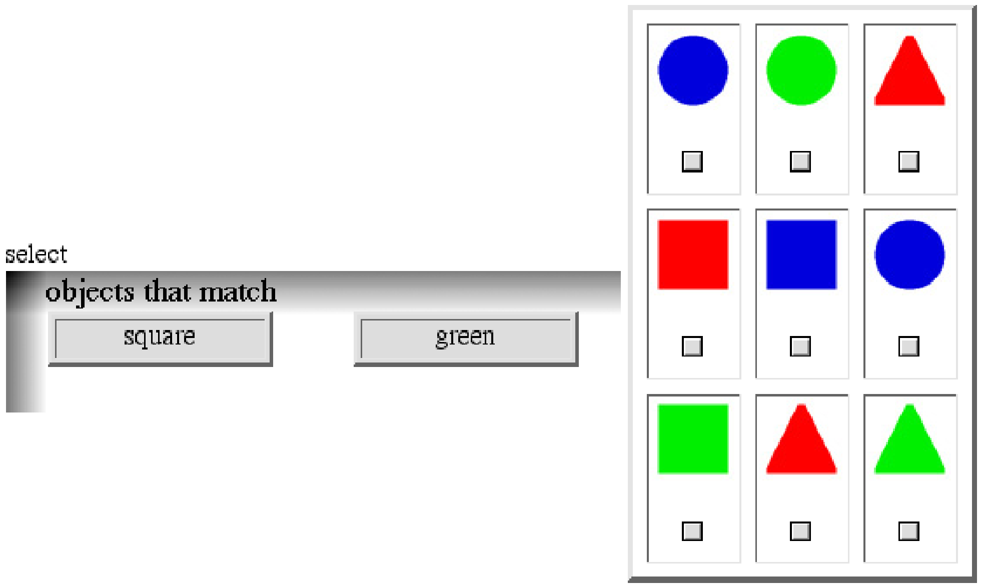
Carefully consider **exactly** which objects we are describing, and mark them by clicking the boxes under them. This can be a little tricky, so please check your answer to be sure that it is right.

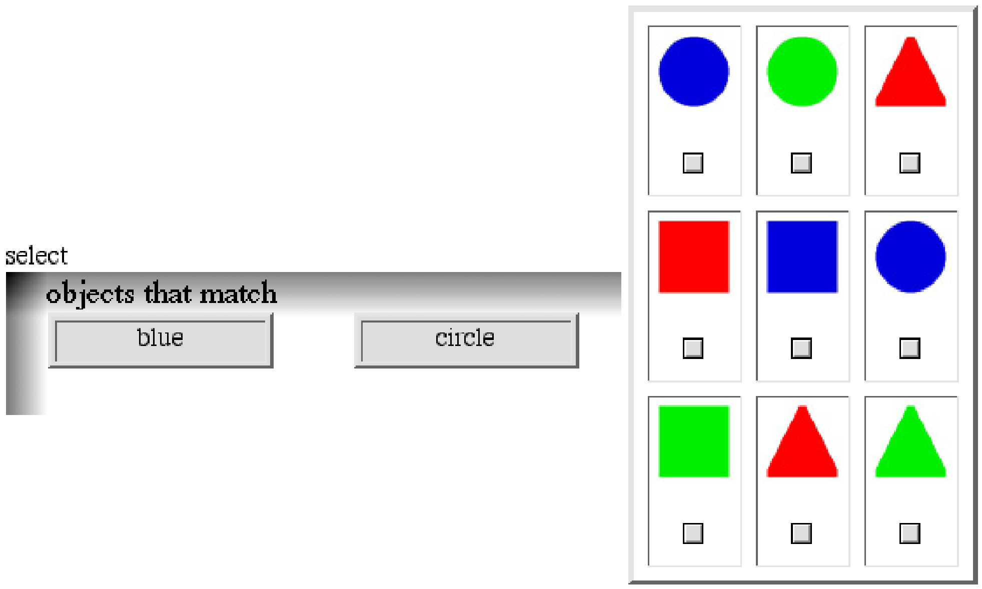
Example:

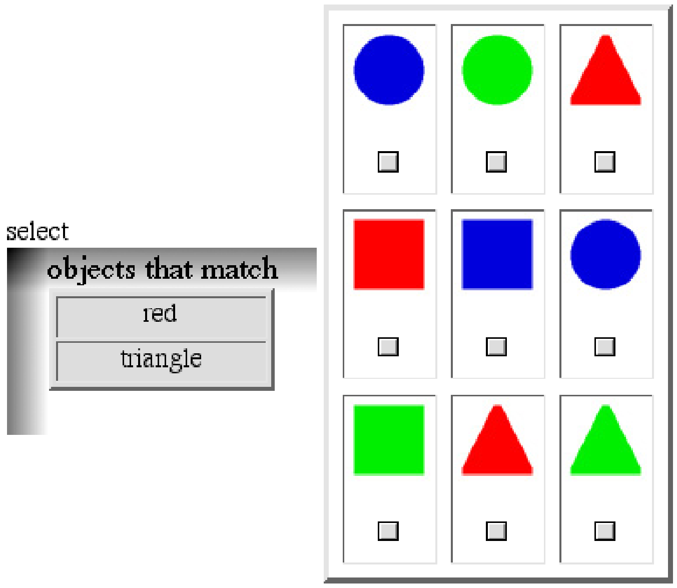

All of the objects will be start out unmarked, like this:
You will mark the objects that are described, like this:
select
objects that match
red

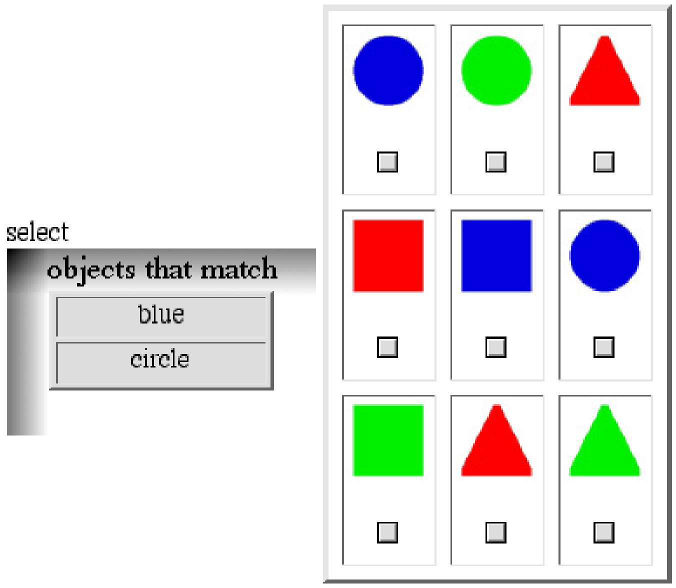
When you are ready to begin, please press the "Ready" button.

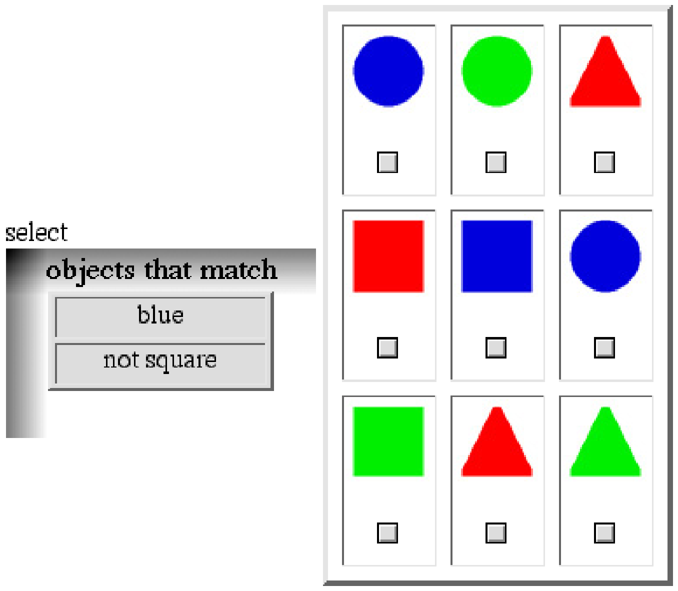
Ready

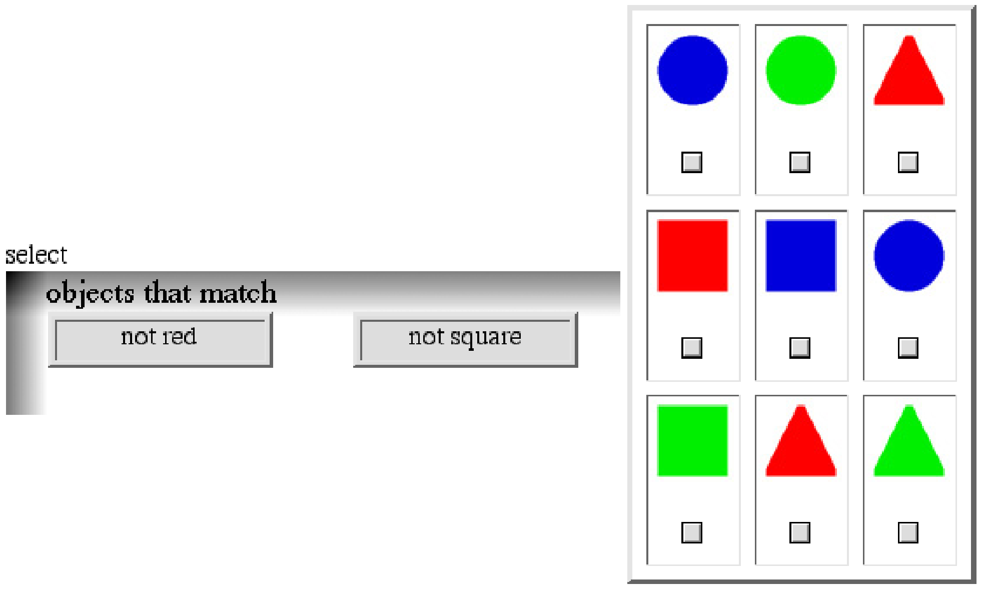

select
objects that match
square
green

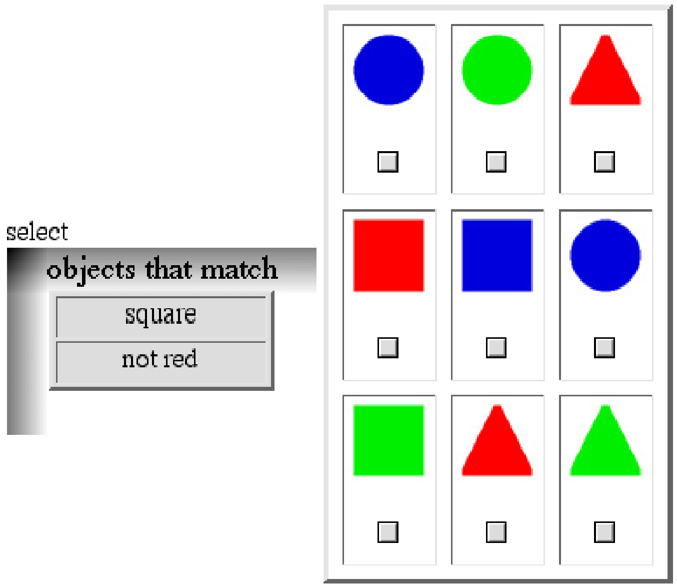

select
objects that match
blue
circle

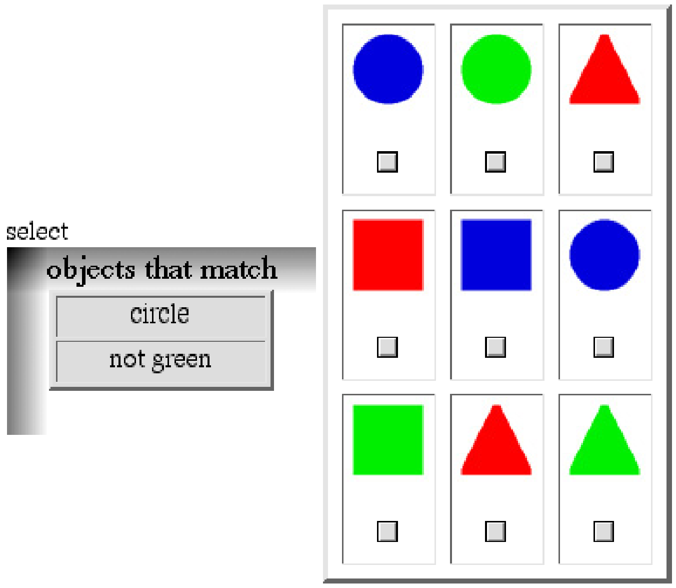

select
objects that match
red
triangle

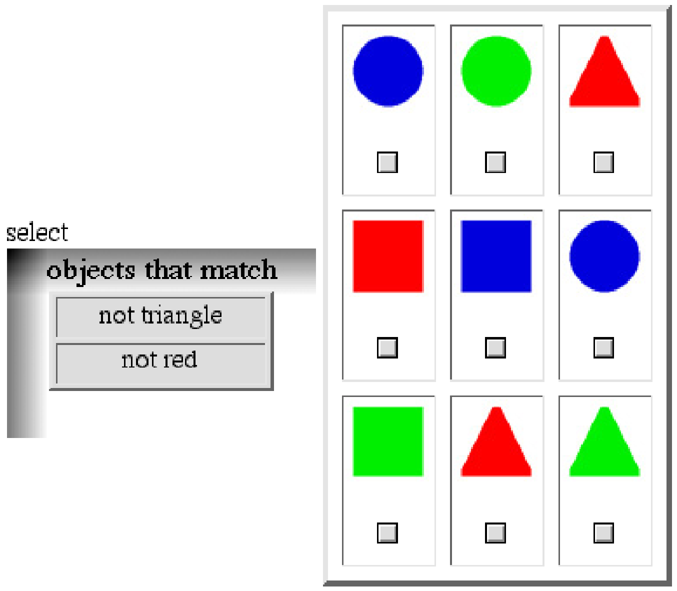

select
objects that match
blue
circle

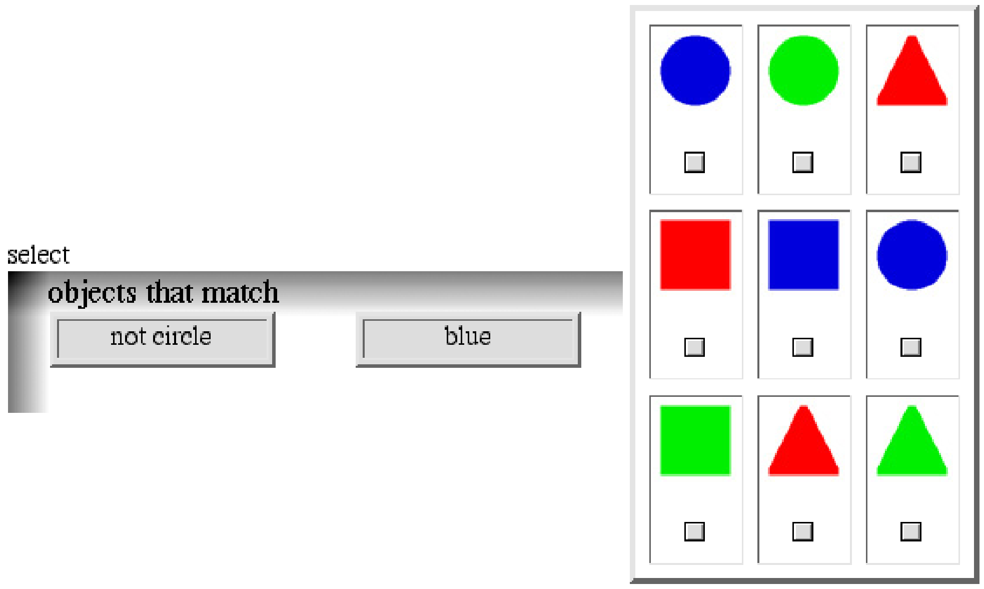

select
objects that match
blue
not square

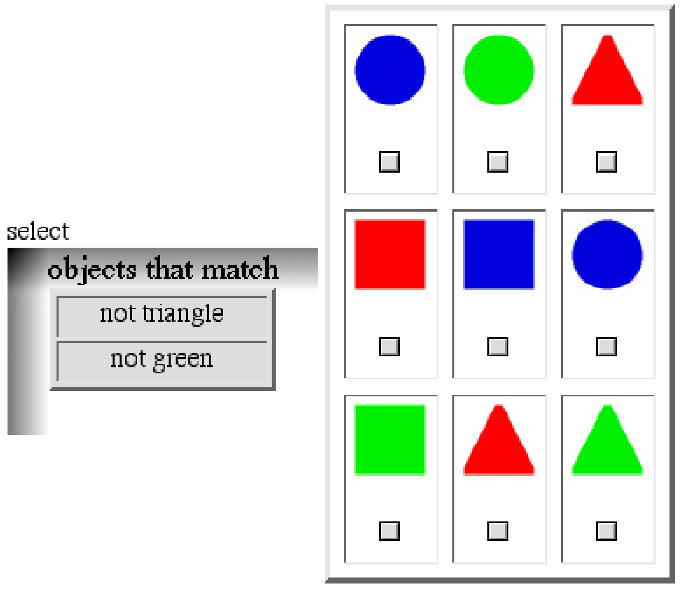

select
objects that match
not red
not square


select
objects that match
square
not red


select
objects that match
circle
not green


select
objects that match
not triangle
not red


select
objects that match
not circle
blue

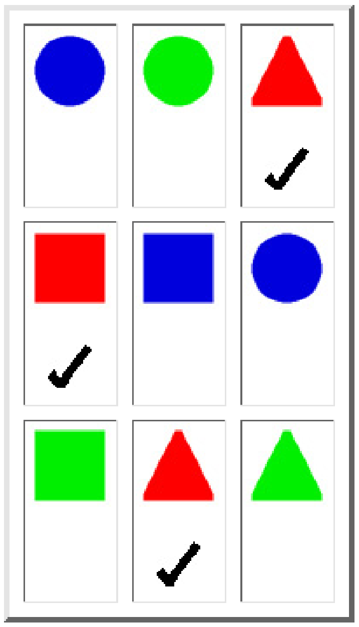

select
objects that match
not triangle
not green

Instructions:

Almost done!

On these last few questions, we are interested in your preferences. We will show you some pictures with the nine objects, and some of them will have checkmarks. There will be a few choices of how to describe them. **All of the choices are correct. We want to know which one you like the best.** Please mark the one that you prefer.

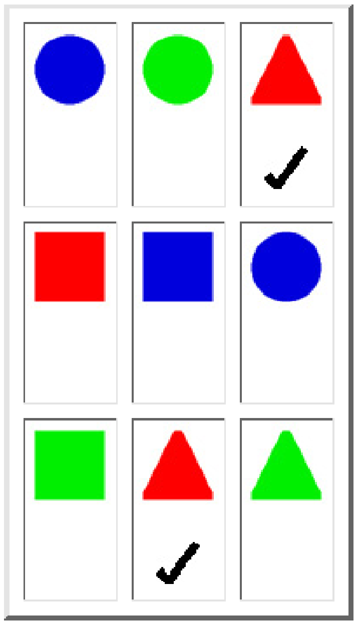
Example:



There will be several choices listed, like this:	**You will pick the one you like the best, like this:**
○ select the objects that match not (blue or green)	○ select the objects that match not (blue or green)
○ select the objects that match red	[✓ select the objects that match red]
○ select the objects that match (not blue) and (not green)	○ select the objects that match (not blue) and (not green)

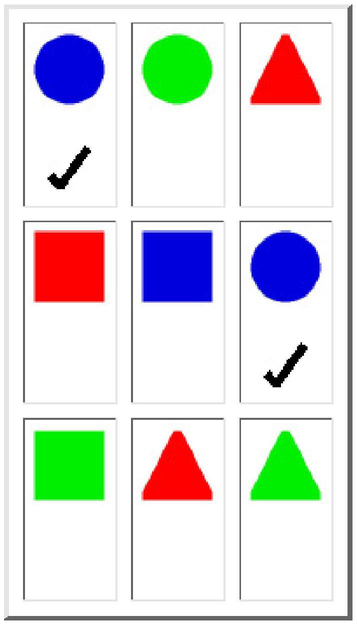
When you are ready to begin, please press the "Ready" button.

Ready



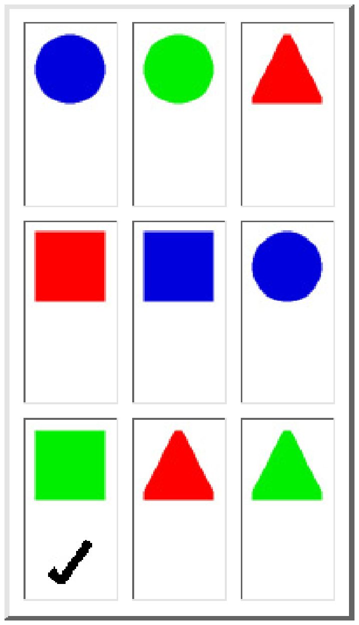
Which description do you like best?

- ○ select the objects that match red, unless the objects match square
- ○ select the objects that match red and not square
- ○ unless the objects match square, select the objects that match red



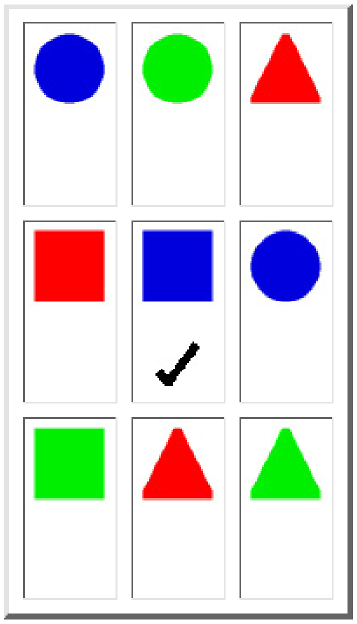
Which description do you like best?

- ○ select the objects that match circle, unless the objects match green
- ○ unless the objects match green, select the objects that match circle



Which description do you like best?

- select the objects that match green and square
- select the objects that match green, if the objects match square

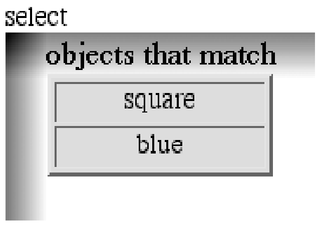


Which description do you like best?

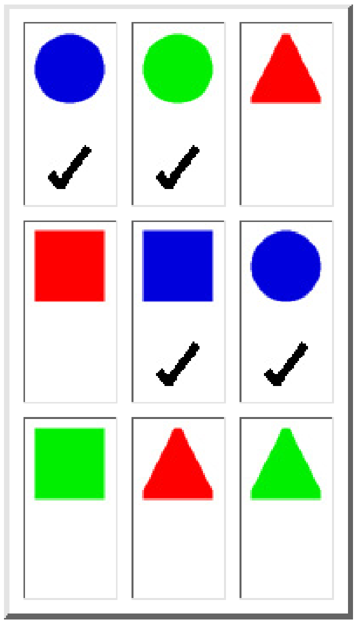
○ (words)

select the objects that match square and blue

○ (match form)

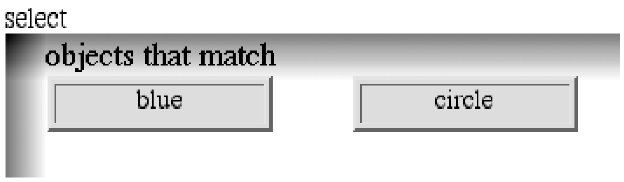


select
objects that match
square
blue



Which description do you like best?

○ (match form)



select

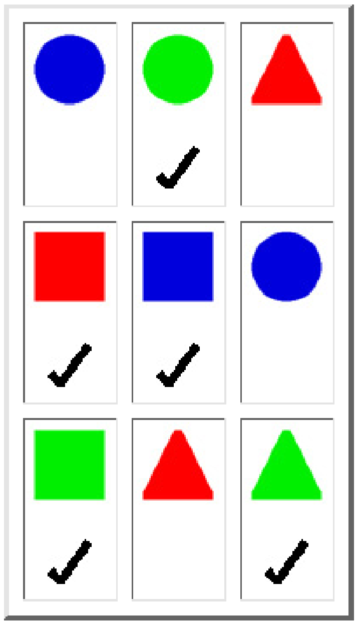
objects that match

blue

circle

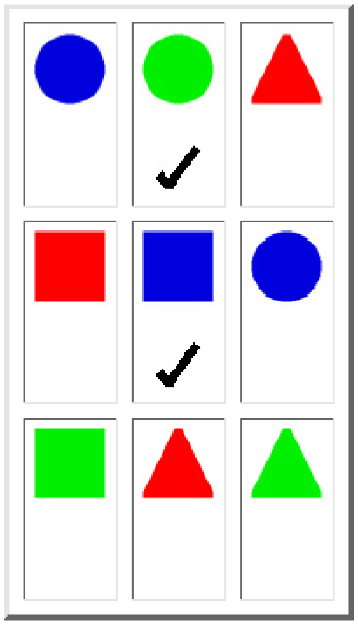
○ (words)

select the objects that match blue or circle



Which description do you like best?

- ○ select the objects that match square or green
- ○ select the objects that match square and the objects that match green

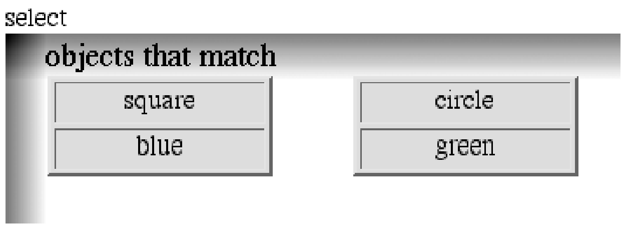


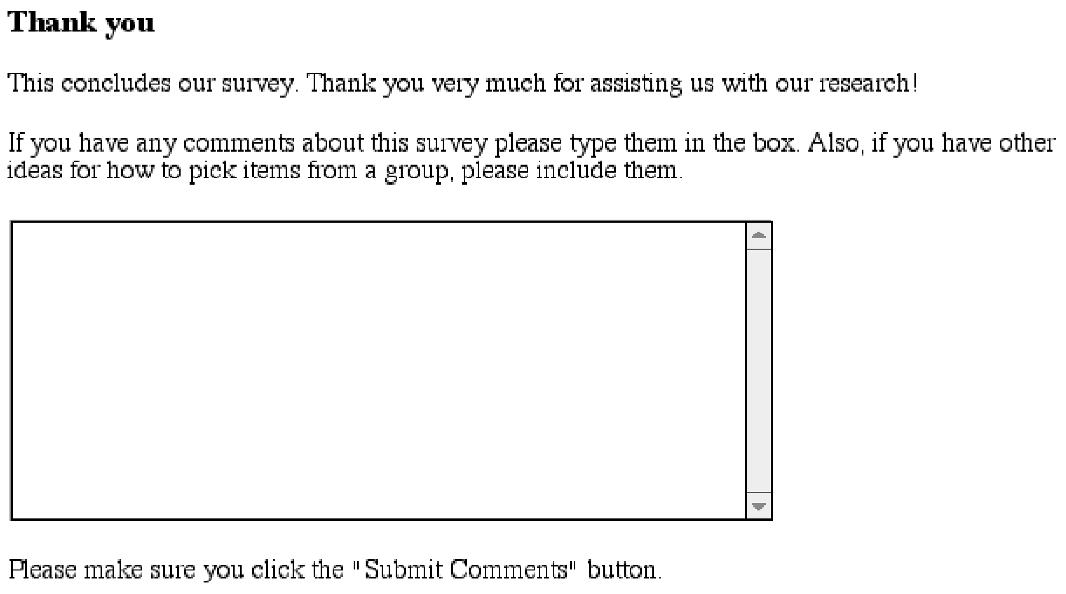
Which description do you like best?

○ (words)

select the objects that match (square and blue) or (circle and green)

○ (match form)





Thank you

This concludes our survey. Thank you very much for assisting us with our research!

If you have any comments about this survey please type them in the box. Also, if you have other ideas for how to pick items from a group, please include them.

Please make sure you click the "Submit Comments" button.

APPENDIX G Materials from Study 4

The following pages contain the materials from Study 4. First the materials for the HANDS condition are presented, followed by the materials for the comparison condition. For each, the following three items appear: the tutorial, the tasks, and the program the participants started with when they began the tasks.

Student Number________________

The HANDS Tutorial

Welcome to HANDS!

HANDS is a way for kids to create things like games on the computer. This tutorial will teach you some important things you can do with HANDS. Once you understand them, you will be ready to make your own games.

First, let's look at what we have to work with:

- The ***game board*** is the large white square in the center. This is where all of the action takes place.
- ***Handy*** is the character in the top left corner. He keeps track of the rules of each game and makes things happen when the game is running. When you want something to happen, you have to tell Handy how to do it.
- Below the game board are ***control buttons***. We can use these to run our game.
- There is also a stack of ***cards*** in the top right. We will keep all of our information on cards.
- Soon you will understand how to use all of these parts.

Let's create a world where bees fly around and land on flowers to gather nectar. Whenever you see this: , there is an action step for you to do. When you complete the step, put a check mark in the box to keep track of your progress. If you follow all of the action steps, and try to learn along the way, you will be in great shape!

Creating cards

Please write down what time it is now ________________.

The first things we need in this world are some flowers. To create an object, you will make a card for it. Then you can use the card to keep track of everything that you want Handy to know about the object.

Now, let's create a flower.

Take a new card from the pile on the table. You can do this by clicking with the mouse on the top of the pile. Do you see how a new card appeared on the table? This will be the card for our first flower.

Each card has a front and a back. The front of the card shows all of the information about the object. The back of the card shows what the object looks like. When you first add a card, it's front is facing up. We can flip the card over to see the other side. When you want to see the back of a card, you can flip it over by clicking on the “X” on the top right of the card.

Let's look at the back of this card.

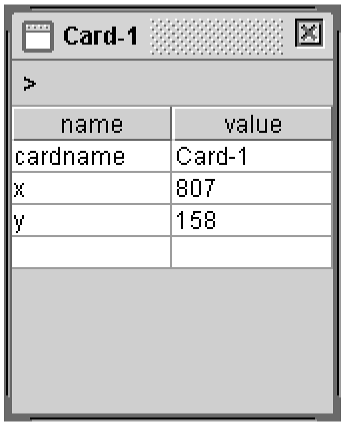
Flip the card over by clicking on the x on the top right of the card.

There isn't much to see on the back of the card because we still have to tell Handy what it should look like.

Let's take another look at the front of this card. When you want to see the front of a card, you can flip it over again by clicking on the back of the card.

Flip the card over by clicking anywhere on the back of the card.
The front of the card has spaces on it; this is where we can add information. Each row on the card is a **property**. It has a pair of boxes to hold information: the boxes on the left are called **name** boxes; the boxes on the right are called the **value** boxes. Soon you will see what these names and values are for.

Handy gives each new card three properties to start with. We can see the names of these properties by looking at the name boxes. Can you see the names of the three properties that we are starting with? The properties are named: `cardname`, `x`, and `y`. Now let's find out what these properties mean.



name	value
cardname	Card-1
x	807
y	158

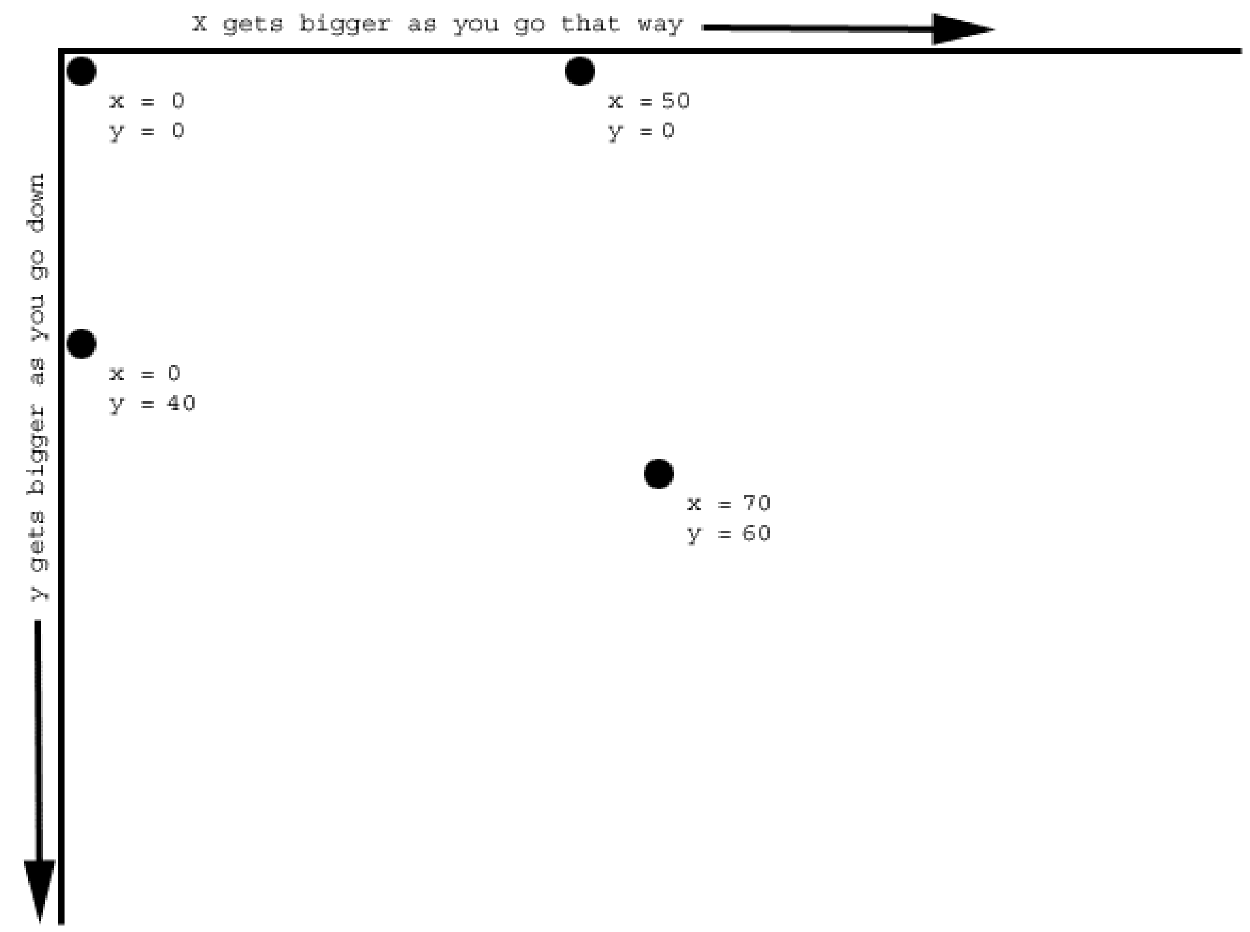
Look at this card's first property, *cardname*. The value box for the cardname property has the name of the card, *Card-1*. Since we haven't named our flower yet, Handy has given it this name to start with. Handy also shows the card's name at the very top of the card. Do you see it?

We would like to name our flower something different. Lets name it Rose. We can change the value of a property by double-clicking in the value box, and changing what is says.

Double-click in the value box for the cardname property. This is the box that says `Card-1` *right now.*
Delete the name Card-1 and type Rose as the new name. Press Enter.
Handy sees when you change the card's name, and he copies it to the top of the card. Do you see the new name Rose at the top now?

x and *y* are properties that describe the card's position on the table. The way we use x and y is like this: start at the top left corner of the screen. At this corner, the value for x is 0 and the value for y is 0; this is like a starting point. If we want to move an object's position toward the right of the screen, we add more to x. If we want to move an object down on the screen, we add more to y.

The picture on the next page shows some examples.


X gets bigger as you go that way
x = 0
y = 0
x = 50
y = 0
x = 0
y = 40
x = 70
y = 60
y gets bigger as you go down

You can move the card around the table by clicking on the blue part at the top of the card and holding down the button while you move the mouse.

Watch to the x and y values while you move the card to a new location.
Did you see the values of the x and y properties changing? If you didn't see it, try again. Handy sees that when the card moves, its x and y properties are different. So, he puts the new x and y values on the card.

Handy will also move the card to the location that the property says. So, we can type in a new value for the x and y properties, and Handy will move the card there for us.
Change the card's location by deleting the current value of the x property and typing in `200`. Press Enter.
Did you see the card move after you pressed Enter?
Now delete the current y value and put in `320`. Press Enter.

There is a blank line at the bottom of the card so we can add more properties to a card than the three that it starts with. We can even tell Handy to change how the card looks. Do you remember that the back of the card shows what the object looks like? Let's look again at the back of this card.
Flip the card. Right now we just see the regular design for the back of a card.
It doesn't look like a flower yet because we haven't added any properties that tell the object how to look.
Flip the card over again to see the front.

Whenever you type information for Handy to read, you have to be extra careful to spell everything the right way. This is because Handy is picky, and can only understand words when they are typed in the exact way that he knows.

`Back` is a special word that Handy will recognize when it is the name of a property. Lets make a property named `back` that will tell Handy what to show on the back of the card.
In the blank name box on the left side of the card, below `y`*, type* `back`*. Press Enter.*

Once you create a new property name, Handy will fill in the value of the property with `0`. This is just so that every property that has a name always has a value. You can change the value of your new property from `0` to whatever you choose.

Now we can decide what the flower will look like. We already have a picture we will use for the Rose. The name of the picture is `rose.gif`.
On the right side of the back property, type `rose.gif` *into the value box. You will have to delete the starting value of* `0` *first. Press Enter.*
Flip the card over to look at the back again.
Do you see the picture of the flower now?
When Handy sees the name of a picture in the back property, he puts that picture on the back of the card. If you do not see a picture on the back of your card, make sure you typed it exactly how it appears above.

Believe it or not, Handy doesn't know that the Rose is a flower. We have to help him by putting that information on the card.
Flip the Rose card over again so that we can see the front of the card.
Add a property named `kind` *to the Rose, and set the value of this property to* `flower`. *Press Enter.*

We can add any other information that we want to the card by just adding more properties. What sorts of things would we want Handy to know about this flower? We could make properties for things like the type of flower it is, the color it is, or the number of petals it has. Let's make a property for how much nectar this flower has.
Double click on a blank name box and type `nectar` *as the name. Press Enter.*
Set the value of the `nectar` *property to 25.*

We can add any other information that we want to the card by just adding more properties, but we do not need to add any more right now. Instead lets make two more flowers and a bee.

One easy way to make a new card is to copy one that is similar. On the front of the Rose card, you can get a menu by clicking on the > symbol above the properties.
Make sure you are seeing the front of the Rose card.
Click the > symbol, and select the command "Duplicate Card". Handy makes a copy of the Rose card right on top of it, and names it Rose-copy1. The original Rose card is underneath. He gives the new card a different name because every card must have a different name.
Move the card Rose-copy1 to the side so we can see both cards.
Change its `cardname` *property to* `Lily`.
Change its back property to `lily.gif`.

Look at the back of the card to make sure Handy found the picture.

Now, we will make a Sunflower.
Create a Sunflower in the same way, by using the "Duplicate Card" command to copy one of the existing cards.
Move the Sunflower so it is next to the other flowers on the game board.
Change the copy's `cardname` *property to* `Sunflower`.
Change its back to `sunflower.gif`.
Look at the back of the card to make sure Handy found the picture.

Let's make a bee. DO NOT copy another card to make the bee. Make sure you create a new card.
Create a new card by clicking on the pile of New Cards.
Name it `Buzzy` *by setting the cardname property*.
Create a back property and set it to `bee.gif`*.*
Flip the card to make sure Handy found the picture. You can place `Buzzy` *wherever you would like on the game board.*

Let's save our work.
*Go to the Hands menu in the top left corner, and choose **Save**.*
If a Save box comes up, please type your student number into the smaller white box labeled **File name**. Then press the **Save** button.

Running the game

The control buttons are used to run our game.
Press the play button to make the game run.

Handy flips all the cards face down and starts looking for things to do. But we have not told Handy what we want him to do yet, so our game doesn't do anything.

Press the stop button to stop the game. Now we can make changes in the game or add new things to it.

Making things move on the game board

Handy will move a card for us if it has certain properties. The **speed** and **direction** properties tell Handy how to move an object. If a card has a speed of 0, that means that the card is not moving at all. If you set the speed to 15, then the card will move very, very fast. The higher the speed, the faster the movement of the card.
Let's tell Handy how fast we want the bee to fly.
Click on Buzzy to see the front of the card.
Create a property named `speed` *for* `Buzzy`. *Set the value to* `1`.

The direction of an object is the way in which it is moving. We describe direction by using angles. You can look at the direction compass in the bottom right corner of the screen to help you remember which numbers match each direction. If a card has a direction of 0, it will move toward the right side of the screen. A direction of 90 will tell the card to move straight up.

Now let's tell Handy which direction the bee should fly.
Create a property named `direction` *for* `Buzzy`. *You can leave the value set to* `0`.

Let's test how this works.

Press the play button to run our game. Look at Buzzy go!
Now press the Stop button before Buzzy gets too far away!

If you want, Handy can put all the cards back where they were when you pushed Play. This is useful if Buzzy goes off the screen.

Press the Reset button, and answer yes to the question.

We can make Buzzy fly in other directions as well.

Set `Buzzy'` *s direction to* `90`.
Press play to see which way `Buzzy` *flies now*.
Press stop. Then press reset.

We saw how to make Buzzy go to the right of the board and to the top of the board. Can you guess how to make Buzzy go to the left and down? What about to the corners of the game board? Try one!

Please write down what time it is now _________________.

<u>Events</u>

Let’s learn more about what Handy can do. Handy keeps track of the rules of each game and makes things happen when the game is running. To see what Handy knows, we can look at his **thought bubble**. The thought bubble is where we can look at the rules that Handy already knows and add more rules for him to keep track of.

Let’s take a look at the thought bubble.

Click on Handy to open up his thought bubble.

The names of the rules that Handy already knows are in the panel on the left. Handy isn’t keeping track of any rules because we haven’t told him about any yet. Handy has started one for you and called it `unfinished-1`. This name is in red to show that Handy does not understand it yet. The big panel to the right is where we tell Handy exactly what we want the rule to do. **Handy will only understand rules written a certain way.**

Handy accomplishes things by watching for **events**. A rule tells Handy which events are important, and what to do when those events happen. Here is an outline for all of Handy’s thoughts:

```
when an event happens
  do some things
end when
```

For each new rule that we make, Handy gives us this to start with:

```
when

end when
```

You can see that it is up to us to fill in two main parts of the rule:

1) the event that Handy should be on the lookout for
2) what things Handy should do when that event happens.

Now let's teach Handy a rule about our game. Let's make a rule that whenever you type “R” on the keyboard, Buzzy will fly to the right. We are already given the outline of the rule. We first need to let Handy know which event to lookout for. The event that we care about is when the `R` key is typed.

Find where the rule says `when`. Change it to say:

```
when R is typed
```

Next we need to tell Handy what things should happen when R is typed. We want Buzzy to fly to the right. Here is how you can tell Handy to do that:

```
set Buzzy's direction to 0
```

Type this instruction into the rule. When you're done, the rule should look like this:

```
when R is typed
     set Buzzy's direction to 0
end when
```

It is important that you write the rule in this special way. If you don't, Handy may not understand what you want him to do. After you write a rule, you can check to see if Handy understands what you wrote.

*Click on the **Check** box above your rule. This will ask Handy to check if he understands your rule.*
Did you see the word OK appear in the bottom panel?

If Handy does not understand your rule, he will let you know what he is confused about. His message will appear in the panel at the bottom of the thought bubble. If you see a message in this window, you should go back and see if you made a typing mistake or if you said something in a different way than Handy would understand.

If Handy does understand your rule, he will change the name of the rule along the left side, and he will make it green. Did Handy rename the rule and make it green? It should now be called `R is typed`. Handy names the rules according to what event he needs to always watch for.

Let's now add three more rules for Buzzy. We will add a rule for Buzzy to move left, one for Buzzy to move up and one for him to move down.

First let's create a rule that makes Buzzy move to the left when you type the letter "L" on the keyboard.

Create a new rule by pressing the New button.
Tell Handy to watch for: `when L is typed`
Put this instruction inside the rule:

```
set Buzzy's direction to 180
```

Check to see if Handy understands your new rule by clicking on the check button.
If the rule checks OK and Handy understands it, great! If Handy does not understand it, look at what you typed to see if there are any mistakes. The message from Handy might help you figure out what is wrong.

Let's try what we have so far.

Close Handy's thought bubble. Now we can see the whole game board.
Click on Buzzy and move him to the lower left corner of the game board.
Press the play button.
Can you use the R and L keys to control when Buzzy flies to the right and left?

After you have played for a little while press the stop button so that we can add more to our game. If Buzzy flew off the screen, press Reset to bring him back.

Now is your turn to create the rules for Buzzy to fly in other directions too.
*Create a **new** rule so that Buzzy will fly up toward the top of the screen* `when U is typed`. Use the compass to figure out what the direction should be. Use Check to make sure Handy understands your new rule.

*Create a **new** rule so that Buzzy will fly down toward the bottom of the screen* `when D is typed`. Use Check to make sure Handy understands.

Now there should be four green rules listed at the left side of the thought bubble:

```
    D is typed
    L is typed
    R is typed
    U is typed
```

If you click each of these you can review what your rules do. They should all be very similar, except they will each set Buzzy's direction to a different value.

Let's try our new game out.
Press the play button. Can you use the keyboard to control where Buzzy flies now? Remember, L is left, R is right, U is up, and D is down. Do all of the directions work?
After you have played for a little while press the stop button so that we can add more to our game.
If Buzzy flew off of the screen, press Reset to get him back.

Let's save our work.
*Go to the Hands menu in the top left corner, and choose **Save**.*

Please write down what time it is now _________________.

Collisions

We can make this game more interesting by making Buzzy do something besides fly around. He can collect nectar from the flowers. Each flower has a property to keep track of how much nectar it has left, and Buzzy can have a property to keep track of how much nectar he has collected.
Make sure you have clicked the Stop button.
Add a `Nectar` *property Buzzy's card.*
Buzzy has not collected any nectar yet, so leave the value set to `0`.

What if we wanted to make something special happen whenever Buzzy flies up to a flower? We can tell Handy to take some nectar from the flower and give it to Buzzy.
*Start a **new rule** in Handy's thought bubble.*

When one card touches another card on the game board, the objects have a **collision**. A collision is an event that Handy can look out for. If we want to tell Handy to watch for when Buzzy is in a collision, we tell Handy to do something `when Buzzy collides`.
Make the new rule start with: `When Buzzy collides into any flower`

What should happen when Buzzy collides with a flower?
Tell Handy to do these things:

```
subtract 1 from the flower's Nectar
add 1 to Buzzy's Nectar
beep
```

This tells Handy to decrease the flower's nectar by one, and increase Buzzy's nectar by one. It also asks Handy to beep so we will know each time a collision has happened.

Now, let's test this new rule.
Press the play button, and make Buzzy fly into some of the flowers a few times. Do you hear a beep each time Buzzy collides into a flower?
Press the stop button, ***but do not press Reset****. Look at the front of Buzzy, and see how much nectar he has collected.* He started with zero. Does he have some nectar now?
Look at the flowers to see how much he took from them. The all started with 25. The ones he collided into should have less than 25.

Let's save our work.
Go to the Hands menu in the top left corner, and choose ***Save****.*

Please write down what time it is now ________________.

Testing Your Ideas

When you put rules into Handy's thought bubble, Handy remembers them but he does not perform the actions in the rule right away. He waits until you press the Play button and then if he see an event that matches the rule he will do the actions.

Sometimes you might like to ask Handy to try something for you immediately, instead of making a rule and then waiting for him to see the rule's event. You can use the ***Testing Window*** to ask Handy questions and get his answers right away.

Let's open the Testing Window. Above Handy is a ***Programming*** menu.
Choose ***Open Testing Window*** *from the* ***Programming*** *menu.*

The Testing Window should be familiar because it is similar to Handy's thought bubble. But the things you type here are not put into Handy's thought bubble. Instead, he will do what you ask *one time only* when you push the ***Test It Now*** button.
Let's try it. Let's ask Handy to do an easy math problem. Type "`1+1`" into the top right of the Testing Window and press ***Test It Now.***
Did you see the number 2 appear in the bottom window? That is Handy telling you the answer. Handy can do harder math problems, and lots of other things.

Go ahead and ask Handy to do a few things.

Lists

Sometimes we want Handy to keep track of a list of items. The special way he makes a list of items is to write them with commas between. Here are two examples of lists:

```
apple, pear, orange, banana
4, 6, 34, -33, 7, 3
```

Handy can also tell us information about a list, if we ask using words he understands. Sometimes these words look funny because they are all squished together without any spaces.

Let's look at an example.

```
     FirstItem in apple, pear, orange
```

This asks Handy to tell us the first item in the list. Can you guess what Handy will tell us? The answer is `apple`.

Try it. Type `FirstItem in apple, pear, orange` *in the Testing Window and press and press* ***Test It Now****.*
Did Handy say `apple` in the bottom window?

Handy can make lists of cards for us. If we want a list of all of the flowers, we can just type `all flowers.`
Type `all flowers` *in the Testing Window and press* ***Test It Now****. Handy gives us a list of all of the flowers.*

Asking Handy to Look for Information

We can ask Handy to look through the cards and search for information about them. Let's make a list of how much nectar each flower has. To do this we have to put together a few pieces. We will ask Handy to find `all flowers` and look into the `nectar` property of each one.
Type `nectar of all flowers` *into the Testing Window and see what Handy replies.*
Did you see a list of numbers in the bottom window? Each of these numbers came from the `nectar` property of one of the flowers.

Let's ask Handy to show us which flower has the *least amount of nectar left*.

Handy understands a way to give us the card with the least value in a certain property. The outline for this question is:

```
     CardWithLeast property of cards
```

We have to fill in two pieces, which **property** Handy should look in, and which **cards** he should look at.

In this case, we would like handy to look in the `nectar` property, and the cards we want him to look at are `all flowers.` So we can say:

```
      CardWithLeast nectar of all flowers.
```

Type `CardWithLeast nectar of all flowers` *into the Testing Window to see what happens*.

If there is a tie, Handy will answer with a list of the flowers that have the least amount of nectar.

Handy also knows how to find the card with the greatest value in a certain property. The word Handy understands for that is: `CardWithGreatest.`

The Build Menu

At the top of the Testing Window there is a **Build** menu. This menu always changes to show you the words Handy understands at the spot where you're typing. If you pick a word from this menu, it is the same as typing it. This could save you some work. For example, you can avoid typing long words like `CardWithLeast`. `CardWithLeast` is listed under the category **List Operators** in the Build menu.

There is also a Build menu in Handy's Thought Bubble. Using the Build menu is optional. You can use the keyboard to type the easier words, or all of them if you want to.

Please write down what time it is now ________________.

Displaying Answers on the Game Board

Now that we can get such great information from Handy, we should find a way to display it for everyone to see. We can create a card to keep track of which flower currently has the least nectar.

Close the Testing Window and create a new card. Give it the name `leastFlower`.
Create a `back` *property for the leastFlower card. It's ok to leave it set to zero.*
Move the leastFlower card onto the game board and flip it over. Right now, you should see the zero that's in the back property of the card.

A minute ago, Handy told us which flower has the least nectar in the Testing Window. But the answer could change while the game is running and Buzzy is taking nectar from the flowers. We would like Handy to keep us informed as soon as the answer changes. So we have to put the command into a rule. If we want Handy to check a rule all of the time, the event we want him to be on the lookout for is `when anything happens`.

Open Handy's Thought Bubble.
Use the New button to make a new rule.
Type `when anything happens` *for the event. This way Handy will do the action* ***all the time*** *when anything happens on the game board.*

We know we want Handy to figure out the `CardWithLeast nectar of all flowers`. We would like him to put the answer into the back property of the leastFlower card. To do this, we will ask him to:

`set` **`leastFlower's back`** `to` **`CardWithLeast nectar of all flowers`**

Put that inside your new rule.

The rule should look like this:

```
when anything happens
    set leastFlower's back to CardWithLeast nectar of all flowers
end when
```

Press Check, to make sure the new rule is correct. If it is, close Handy's Thought Bubble.
Press Play to see what happens. Did Handy change the back of leastFlower to tell us which card or cards have the least nectar?
Have Buzzy land on a few flowers and watch what happens to the flower with least value. Did it change at all?
Press the stop button when you are finished.

Let’s save our work.
*Go to the Hands menu in the top left corner, and choose **Save**.*

Please write down what time it is now _________________.

Adding up lists of numbers

What if we were going to create more bees to gather honey with Buzzy. We would have to make sure that there is enough nectar to go around. Handy can help us figure out how much nectar the flowers have altogether.

If we give Handy a list of numbers, he can add them up for us.
Open the Testing Window, and type `sum 1,2,3`
Handy adds up the numbers.

Earlier we used `nectar of all flowers` to make a list of the nectar in all of the flowers. If we want Handy to sum up all of these values we can combine this with the sum command like this:

```
     sum the nectar of all flowers
```

Try that in the Testing Window.
When we ask this way, Handy adds up all of the nectar in all of the flowers.

Now let’s make a card for Handy to put the answer in.
Close the Testing Window and make a card named `total`.
Create a `back` *property for the total card. It’s ok to leave it set to zero.*
Move the total card onto the game board and flip it over. Right now, you should see the zero that’s in the back property.

We want Handy to always update the total card have the correct total nectar. Do you remember what event we want Handy to watch for if we want him to check a rule all of the time? It is `when anything happens`. Since we already have a rule for `anything happens` we will add another instruction to it.
In Handy’s Thought Bubble, add another instruction to the `when anything happens` *rule. The new instruction is*:

```
     set total’s back to sum the nectar of all flowers
```

Now your `anything happens` rule should look something like this.

```
when anything happens
 set leastFlower’s back to CardWithLeast nectar of all flowers
 set total’s back to sum the nectar of all flowers
end when
```

Press Check to make sure Handy understands the rule.
Press Play and watch what happens when Buzzy takes nectar from the flowers.
Handy should update the `total` card to always show how much nectar the flowers have altogether.

Let’s save our work.
*Go to the Hands menu in the top left corner, and choose **Save**.*

Please write down what time it is now _________________.

Making Changes to lots of objects that are the same kind

What if there isn't enough nectar for a large group of bees? Let's tell Handy to give ten more nectar to each of the flowers when we type the "n" key. To do this, we will combine two things we learned earlier:

1) Remember when we were writing the rule for when Buzzy lands on a flower? We used `subtract 1 from the flower's nectar` to take some nectar from the flower. Handy can also do addition or subtraction on a whole list of items, such as the nectar properties of all of the flowers.
2) Remember when we wanted Handy to make a list of the nectar in all of the flowers? We used `nectar of all flowers` to do this.

Let's combine these two ideas to accomplish our goal. We can ask Handy to:

```
     add 10 to the nectar of all flowers
```

Handy will go to every flower and add 10 to its nectar property.

In Handy's Thought Bubble, create a new rule to do this `when N is typed`:

```
when N is typed
     add 10 to the nectar of all flowers
end when
```

Press Check, to make sure Handy understands the rule.
Press Play, and try it out by pressing the N key.

Did you see the total nectar increase by 30 each time you pressed the N key? This is because there are 3 flowers, and each one gets 10 added to its nectar.

Let's save our work.
*Go to the Hands menu in the top left corner, and choose **Save**.*

Please write down what time it is now ________________.

Congratulations! You have completed the HANDS Tutorial. You were able to make a fun world with bees and flowers, and hopefully, you learned a lot about HANDS along the way.

Student Number________________

Great job! Now that you have learned so much about HANDS, you are ready to try to do some more things on your own.

Here is a new game similar to the one you created. Buzzy went back to the hive and told all of the bees about the wonderful flowers he found. Now lots of Buzzy's friends have come to gather nectar with him. To help us keep track of Buzzy, he is bigger than all the other bees. You can still control Buzzy with the U, D, L and R keys.

All of the bees now have a special property so Handy knows they are bees. This is the property named kind with the value bee. You can see this for yourself on each bee card. Handy knows some rules to make the bees fly around and collect nectar on their own.

Can you add some things to this new game? You can refer to the tutorial if you need some hints.

Please write down what time it is now ________________.

1. Display the name of the bee that collected the greatest amount of nectar.
A card named bestBee has been created for this problem. Have Handy check which bee has the greatest amount of nectar, and put the answer into the back property of bestBee. Handy should always update this information while the game is running. This means he should do it `when anything happens`.

Hint: It may be useful to review page 10 of the tutorial, in the section "Asking Handy to Look for Information".

Run your game to check if it works. The first set of question-marks (???) should be replaced by the name of the bee with the greatest amount of nectar.
Go to the Hands menu in the top left corner, and choose **Save**.
Please write down what time it is when you finish this problem ________________.

2. Make all of the bees stop flying when the S key is typed.
You will need to set their speed to 0.

Hint: It may be useful to review page 7 of the tutorial.

Run your game to check if it works. All of the bees should stop when you press the S key.
Go to the Hands menu in the top left corner, and choose **Save**.
Please write down what time it is when you finish this problem ________________.

3. Let all of the bees fly again when the G key is typed.
They should fly at the speed of 1.

Run your game to check if it works. All of the bees should go when you press the G key.
Go to the Hands menu in the top left corner, and choose **Save**.
Please write down what time it is when you finish this problem ________________.

4. Display how much nectar all of the bees have collected.
A card named beeTotal has been created to for this problem. Tell Handy to add up how much nectar all the bees have, and put the answer into the back property of beeTotal. Handy should update this as often as possible.

Hint: You may find useful information on page 12 of the tutorial, in the section "Adding up lists of numbers".

Run your game to check if it works. The third set of question-marks (???) should be replaced by the total amount of nectar collected by all of the bees.
Go to the Hands menu in the top left corner, and choose **Save**.
Please write down what time it is when you finish this problem ________________.

5. Add another bee to the world.
Copy one of the existing bees and name it with your best friend's name.

Hint: Look at the bottom of page 4 in the tutorial if you forgot how to copy cards.

Run your game to check if it works. Your new bee should stop when the S key is hit, and go again when the G key is hit. If your new bee does not stop and go, try to figure out why and fix it.
Go to the Hands menu in the top left corner, and choose **Save**.
Please write down what time it is when you finish this problem ________________.

That's all. Thanks for your help!

BONUS PROBLEM:
If you have extra time, you can try this bonus problem.

6. Display how much nectar the best bee has.
A card named mostNectar has been created for this problem. Tell Handy to figure out how much nectar the best bee has, and put the answer into the back property of mostNectar. Handy should update this as often as possible.

Hint: You will need to use your answer to problem 1 as part of your answer here.

Run your game to check if it works. The second set of question-marks (???) should be replaced by the amount of nectar collected by the best bee.
Go to the Hands menu in the top left corner, and choose **Save**.
Please write down what time it is when you finish this problem ________________.

```
beeTotal x:406 y:60 back:"???";
beeTotalSign x:200 y:60 back:"All the bees have collected:";
bestBee x:406 y:20 back:"???";
bestBeeSign x:200 y:20 back:"The bee with the most nectar is:";
Bumbles x:530 y:60 kind:bee back:bumbleb.gif nectar:5 speed:1 direction:270;
Bumbles2 x:465 y:35 kind:bee back:bumbleb.gif nectar:5 speed:1 direction:270;
Buzzy x:575 y:152 kind:bee back:bee.gif nectar:0 speed:3 direction:270;
Buzzy2 x:677 y:102 kind:bee back:bumbleb.gif nectar:6 speed:1 direction:270;
Fuzzy x:450 y:120 kind:bee back:bumbleb.gif nectar:3 speed:1 direction:270;
Fuzzy2 x:580 y:290 kind:bee back:bumbleb.gif nectar:7 speed:1 direction:270;
Honey x:280 y:230 kind:bee back:bumbleb.gif nectar:7 speed:1 direction:270;
Honey2 x:490 y:260 kind:bee back:bumbleb.gif nectar:1 speed:1 direction:270;
Killer x:650 y:90 kind:bee back:bumbleb.gif nectar:0 speed:1 direction:270;
Killer2 x:205 y:108 kind:bee back:bumbleb.gif nectar:0 speed:1 direction:270;
Lily x:318 y:329 kind:flower back:lily.gif nectar:100;
Lily2 x:675 y:308 kind:flower back:lily2.gif nectar:100;
mostNectar x:406 y:40 back:"???";
mostNectarSign x:200 y:40 back:"He has this much nectar:";
Rose x:205 y:319 kind:flower back:rose.gif nectar:100;
Rose2 x:465 y:328 kind:flower back:rose2.gif nectar:100;
Stripes x:300 y:150 kind:bee back:bumbleb.gif nectar:8 speed:1 direction:270;
Stripes2 x:403 y:202 kind:bee back:bumbleb.gif nectar:3 speed:1 direction:270;
Sunflower x:555 y:330 kind:flower back:sunflower.gif nectar:100;
when any bee collides into any flower
       subtract 1 from flower's nectar
       add 1 to bee's nectar
       beep
end when
when D is typed
       set buzzy's direction to 270
       set buzzy's speed to 3
end when
when L is typed
       set buzzy's direction to 180
       set buzzy's speed to 3
end when
when program starts
       with all bees calling each b
              set direction of b to random 240 to 300
       end with
end when
when R is typed
       set buzzy's direction to 0
       set buzzy's speed to 3
end when
when U is typed
       set buzzy's direction to 90
       set buzzy's speed to 3
end when
```

Student Number________________

The HANDS Tutorial

Welcome to HANDS!

HANDS is a way for kids to create things like games on the computer. This tutorial will teach you some important things you can do with HANDS. Once you understand them, you will be ready to make your own games.

First, let's look at what we have to work with:

- The ***game board*** is the large white square in the center. This is where all of the action takes place.
- ***Handy*** is the character in the top left corner. He keeps track of the rules of each game and makes things happen when the game is running. When you want something to happen, you have to tell Handy how to do it.
- Below the game board are ***control buttons***. We can use these to run our game.
- There is also a stack of ***cards*** in the top right. We will keep all of our information on cards.
- Soon you will understand how to use all of these parts.

Let's create a world where bees fly around and land on flowers to gather nectar. Whenever you see this: , there is an action step for you to do. When you complete the step, put a check mark in the box to keep track of your progress. If you follow all of the action steps, and try to learn along the way, you will be in great shape!

Creating cards

Please write down what time it is now ________________.

The first things we need in this world are some flowers. To create an object, you will make a card for it. Then you can use the card to keep track of everything that you want Handy to know about the object.

Now, let's create a flower.
Take a new card from the pile on the table. You can do this by clicking with the mouse on the top of the pile. Do you see how a new card appeared on the table? This will be the card for our first flower.

You can move the card around the table by clicking on the blue part at the top of the card and holding down the button while you move the mouse.
Move the card so it is in the middle of the game board (the big white square).

Each card has a front and a back. The front of the card shows all of the information about the object. The back of the card shows what the object looks like. When you first add a card, it's front is facing up. We can flip the card over to see the other side. When you want to see the back of a card, you can flip it over by clicking on the “X” on the top right of the card.

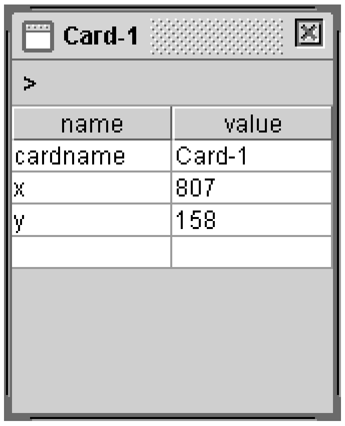
Let's look at the back of this card.
Flip the card over by clicking on the x on the top right of the card.

There isn't much to see on the back of the card because we still have to tell Handy what it should look like.

Let's take another look at the front of this card. When you want to see the front of a card, you can flip it over again by clicking on the back of the card.

Flip the card over by clicking on the back of the card.
The front of the card has spaces on it; this is where we can add information. Each row on the card is a **property**. It has a pair of boxes to hold information: the boxes on the left are called **name** boxes; the boxes on the right are called the **value** boxes. Soon you will see what these names and values are for.

Handy gives each new card three properties to start with. We can see the names of these properties by looking at the name boxes. Can you see the names of the three properties that we are starting with? The properties are named: `cardname`, `x`, and `y`. Now let's find out what these properties mean.


Card-1

>

name	value
cardname	Card-1
x	807
y	158

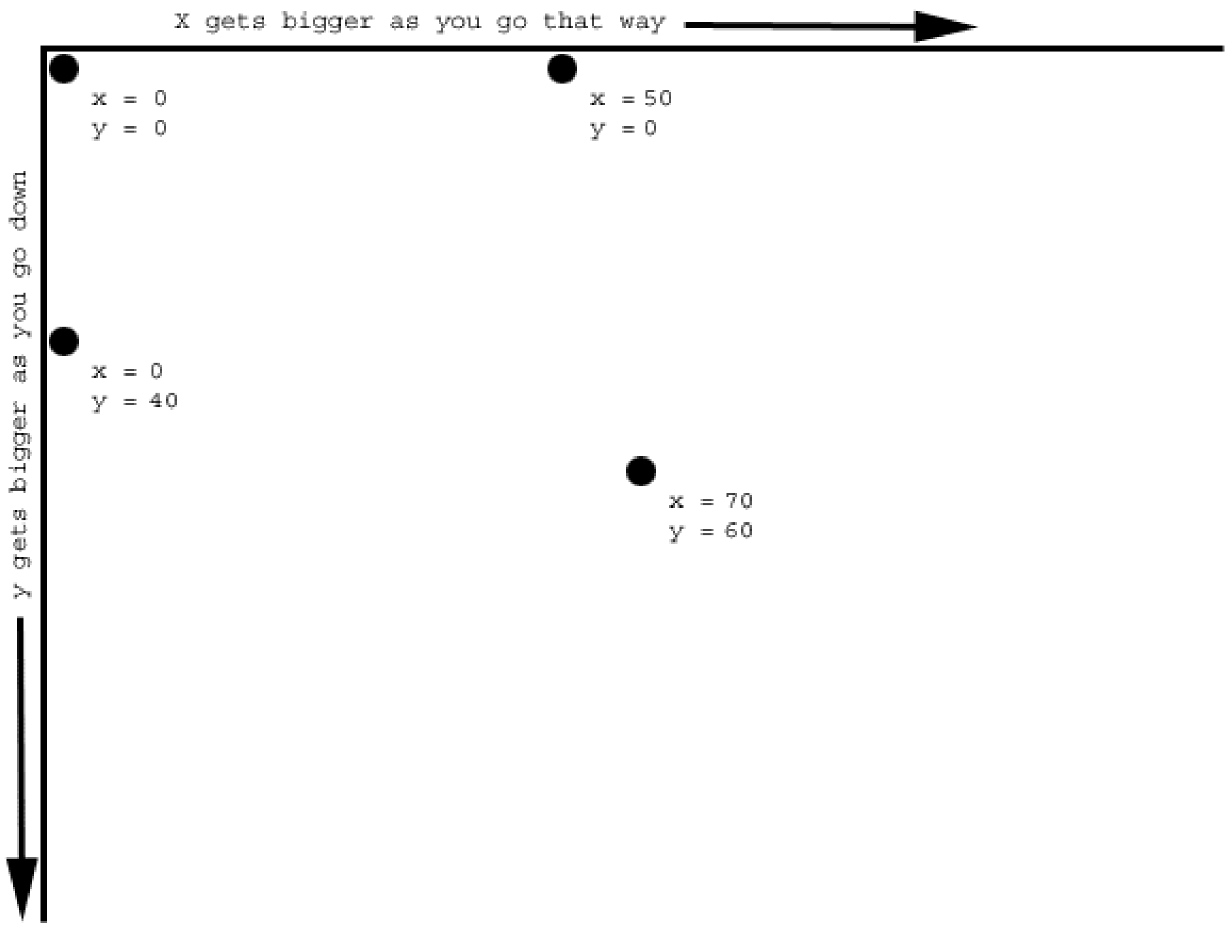
Look at this card's first property, *cardname*. The value box for the cardname property has the name of the card, *Card-1*. Since we haven't named our flower yet, Handy has given it this name to start with. Handy also shows the card's name at the very top of the card. Do you see it?

We would like to name our flower something different. Lets name it Rose. We can change the value of a property by double-clicking in the value box, and changing what is says.

Double-click in the value box for the cardname property. This is the box that says `Card-1` *right now.*
Delete the name Card-1 and type Rose as the new name. Press Enter.
Handy sees when you change the card's name, and he copies it to the top of the card. Do you see the new name Rose at the top now?

x and *y* are properties that describe the card's position on the table. The way we use x and y is like this: start at the top left corner of the screen. At this corner, the value for x is 0 and the value for y is 0; this is like a starting point. If we want to move an object's position toward the right of the screen, we add more to x. If we want to move an object down on the screen, we add more to y.

This picture shows some examples.


X gets bigger as you go that way
x = 0
y = 0
x = 50
y = 0
x = 0
y = 40
x = 70
y = 60
y gets bigger as you go down

Watch to the x and y values while you move the card to a new location.
Did you see the values of the x and y properties changing? If you didn't see it, try again. Handy sees that when the card moves, its x and y properties are different. So, he puts the new x and y values on the card.

Handy will also move the card to the location that the property says. So, we can type in a new value for the x and y properties, and Handy will move the card there for us.
Change the card's location by deleting the current value of the x property and typing in `200`. Press Enter.
Did you see the card move after you pressed Enter?
Now delete the current y value and put in `320`. Press Enter.

There is a blank line at the bottom of the card so we can add more properties to a card than the three that it starts with. We can even tell Handy to change how the card looks. Do you remember that the back of the card shows what the object looks like? Let's look again at the back of this card.
Flip the card. Right now we just see the regular design for the back of a card.

It doesn't look like a flower yet because we haven't added any properties that tell the object how to look.
    Flip the card over again to see the front.

Whenever you type information for Handy to read, you have to be extra careful to spell everything the right way. This is because Handy is picky, and can only understand words when they are typed in the exact way that he knows.

`Back` is a special word that Handy will recognize when it is the name of a property. Lets make a property named `back` that will tell Handy what to show on the back of the card.
    In the blank name box on the left side of the card, below `y`*, type* `back`*. Press Enter.*

Once you create a new property name, Handy will fill in the value of the property with `0`. This is just so that every property that has a name always has a value. You can change the value of your new property from `0` to whatever you choose.

Now we can decide what the flower will look like. We already have a picture we will use for the Rose. The name of the picture is `rose.gif`.
    On the right side of the back property, type `rose.gif` *into the value box. You will have to delete the starting value of* `0` *first. Press Enter.*
    Flip the card over to look at the back again.
Do you see the picture of the flower now?
When Handy sees the name of a picture in the back property, he puts that picture on the back of the card. If you do not see a picture on the back of your card, make sure you typed it exactly how it appears above.

Believe it or not, Handy doesn't know that the Rose is a flower. We have to help him by putting that information on the card.
    Flip the Rose card over again so that we can see the front of the card.
    Add a property named `kind` *to the Rose, and set the value of this property to* `flower`. *Press Enter.*

We can add any other information that we want to the card by just adding more properties. What sorts of things would we want Handy to know about this flower? We could make properties for things like the type of flower it is, the color it is, or the number of petals it has. Let's make a property for how much nectar this flower has.
    Double click on a blank name box and type `nectar` *as the name. Press Enter.*
    Set the value of the `nectar` *property to 25.*

We can add any other information that we want to the card by just adding more properties, but we do not need to add any more right now.

We would like to keep a list of all of the flowers. Let's make another card for this.
    Click the pile of new cards to get another card. Leave it off to the side of the board.
    Set the cardname property to `Garden`*.*

The Garden card will contain a property that is a list of all of the flowers we create. Let's make a property for this list.
    In the blank name box on the left side of the Garden card, below `y`*, type* `flowerList`*. Press Enter.*

Right now, the only flower we have created is Rose, so let's put that into the `flowerList` property of the Garden card.

On the right side of the flowerList property, type `Rose` *into the value box. You will have to delete the starting value of* `0` *first. Press Enter.*

Now lets make two more flowers and a bee.

One easy way to make a new card is to copy one that is similar. On the front of the Rose card, you can get a menu by clicking on the > symbol above the properties.

Click on the Rose to flip the Rose card face up.

Click the > symbol, and select the command "Duplicate Card". Handy makes a copy of the Rose card right on top of it, and names it Rose-copy1. The original Rose card is underneath. He gives the new card a different name because every card must have a different name.

Move the card Rose-copy1 to the side so we can see the original Rose.

Change Rose-copy1's `cardname` *property to* `Lily`.

Change its back property to `lily.gif`.

Look at the back of the card to make sure Handy found the picture.

Sometimes we want Handy to keep track of more than one item in a single property. The special way he makes a list of items is to write them with commas between. Here are two examples of lists:

```
apple, pear, orange, banana
4, 6, 34, -33, 7, 3
```

We have to add the new flower to the flowerList property on the Garden card. But, since Garden is not on the board, how can we flip it over?

Go to the Programming menu above Handy, and choose the command ***Show Card List***. This window shows all of the cards in our game.

Click on Garden in this window to flip the Garden card face up.

Add Lily to the flowerList property of Garden, separating it from Rose with a comma. When you're done, the value of the flowerList property should be: `Rose, Lily`

Now, we will make a Sunflower.

Create a Sunflower in the same way, by using the "Duplicate Card" command to copy one of the existing flowers.

Move the new card so it is next to the other flowers on the game board.

Change the new card's `cardname` *property to* `Sunflower`.

Change its back to `sunflower.gif`.

Look at the back of the card to make sure Handy found the picture.

Click on Garden in the Cards window to flip it face up.

Add Sunflower to the flowerList property of Garden, separating it from Lily with a comma. When you're done, the value of the flowerList property should be:

```
Rose, Lily, Sunflower
```

If you can't see the whole contents of the flowerList property, you can make the card larger by clicking one of the edges and holding the mouse button down while you move the mouse. After you're done, make sure that the Garden card is off the board so that it doesn't show at all when it is flipped face down.

Let's make a bee. DO NOT copy another card to make the bee. Make sure you create a new card.

Create a new card by clicking on the pile of New Cards.
Place it wherever you would like on the game board.
Name it `Buzzy` *by setting the cardname property*.
Create a back property and set it to `bee.gif`*.*
Flip the card to make sure Handy found the picture.

Let's save our work.

*Go to the Hands menu in the top left corner, and choose **Save**.*

You can continue with the next section unless a Save box comes up. If a Save box does come up, please type your student number into the smaller white box labeled **File name**. Then press the **Save** button.

<u>Running the game</u>

The control buttons are used to run our game.

Press the play button to make the game run.

Handy makes sure all the cards are flipped face down and starts looking for things to do. But we have not told Handy what we want him to do yet, so our game doesn't do anything.

Press the stop button to stop the game. Now we can make changes in the game or add new things to it.

<u>Making things move on the game board</u>

Handy will move a card for us if it has certain properties. The **speed** and **direction** properties tell Handy how to move an object. If a card has a speed of 0, that means that the card is not moving at all. If you set the speed to 15, then the card will move very, very fast. The higher the speed, the faster the movement of the card.

Let's tell Handy how fast we want the bee to fly.

Click on Buzzy to see the front of the card.
Create a property named `speed` *for Buzzy*. *Set the value to* 1.

The direction of an object is the way in which it is moving. We describe direction by using angles. You can look at the direction compass in the bottom right corner of the screen to help you remember which numbers match each direction. If a card has a direction of 0, it will move toward the right side of the screen. A direction of 90 will tell the card to move straight up.

Now let's tell Handy which direction the bee should fly.

Create a property named `direction` *for* Buzzy. *You can leave the value set to* `0`.

Let's test how this works.

Press the play button to run our game. Look at Buzzy go!
Now press the Stop button before Buzzy gets too far away!

If you want, Handy can put all the cards back where they were when you pushed Play. This is useful if Buzzy goes off the board.

Press the Reset button, and answer yes to the question.

We can make Buzzy fly in other directions as well.
Set `Buzzy's` *direction to* `90`.
Press play to see which way `Buzzy` *flies now*.
Press stop. Then press reset.
We saw how to make Buzzy go to the right of the board and to the top of the board. Can you guess how to make Buzzy go to the left and down? What about to the corners of the game board? Try one!

Please write down what time it is now _________________.

Events

Let's learn more about what Handy can do. Handy keeps track of the rules of each game and makes things happen when the game is running. To see what Handy knows, we can look at his **thought bubble**. The thought bubble is where we can look at the rules that Handy already knows and add more rules for him to keep track of.

Let's take a look at the thought bubble.
Click on Handy to open up his thought bubble.

The names of the rules that Handy already knows are in the panel on the left. Handy isn't keeping track of any rules because we haven't told him about any yet. Handy has started one for you and called it something like `unfinished-1`. This name is in red to show that Handy does not understand it yet. The big panel to the right is where we tell Handy exactly what we want the rule to do. **Handy will only understand rules written a certain way.**

Handy accomplishes things by watching for **events**. A rule tells Handy which events are important, and what to do when those events happen. Here is an outline for all of Handy's thoughts:

```
when an event happens
  do some things
end when
```

For each new rule that we make, Handy gives us this to start with:

```
when

end when
```

You can see that it is up to us to fill in two main parts of the rule:

1) the event that Handy should be on the lookout for
2) what things Handy should do when that event happens.

Now let's teach Handy a rule about our game. Let's make a rule that whenever you type "R" on the keyboard, Buzzy will fly to the right. We are already given the outline of the rule. We first need to let Handy know which event to lookout for. The event that we care about is when the R key is typed.
Find where the rule says `when`. *Change it to say:*

```
when R is typed
```

Next we need to tell Handy what things should happen when R is typed. We want Buzzy to fly to the right. Here is how you can tell Handy to do that:

```
set Buzzy's direction to 0
```

Type this instruction into the rule. When you're done, the rule should look like this:

```
when R is typed
     set Buzzy's direction to 0
end when
```

It is important that you write the rule in this special way. If you don't, Handy may not understand what you want him to do. After you write a rule, you can check to see if Handy understands what you wrote.

*Click on the **Check** box above your rule. This will ask Handy to check if he understands your rule.*

Did you see the word OK appear in the bottom panel?

If Handy does not understand your rule, he will let you know what he is confused about. His message will appear in the panel at the bottom of the thought bubble. If you see a message in this window, you should go back and see if you made a typing mistake or if you said something in a different way than Handy would understand.

If Handy does understand your rule, he will change the name of the rule along the left side, and he will make it green. Did Handy rename the rule and make it green? It should now be called `R is typed`. Handy names the rules according to what event he needs to always watch for.

Let's now add three more rules for Buzzy. We will add a rule for Buzzy to move left, one for Buzzy to move up and one for him to move down.

First let's create a rule that makes Buzzy move to the left when you type the letter "L" on the keyboard.

Create a new rule by pressing the New button.

Tell Handy to watch for: `when L is typed`

Put this instruction inside the rule:

```
set Buzzy's direction to 180
```

Check to see if Handy understands your new rule by clicking on the check button.

If the rule checks OK and Handy understands it, great! If Handy does not understand it, look at what you typed to see if there are any mistakes. The message from Handy might help you figure out what is wrong.

Let's try what we have so far.

Close Handy's thought bubble. Now we can see the whole game board.

Click on Buzzy and move him to the lower left corner of the game board.

Press the play button.

Can you use the R and L keys to control when Buzzy flies to the right and left?

After you have played for a little while press the stop button so that we can add more to our game. If Buzzy flew off the board, press Reset to bring him back.

Now is your turn to create the rules for Buzzy to fly in other directions too.

*Create a **new** rule so that Buzzy will fly up toward the top of the screen* `when U is typed.` Use the compass to figure out what the direction should be. Use Check to make sure Handy understands your new rule.

*Create a **new** rule so that Buzzy will fly down toward the bottom of the screen* `when D is typed`. Use Check to make sure Handy understands.

Now there should be four green rules listed at the left side of the thought bubble:

```
D is typed
L is typed
R is typed
U is typed
```

If you click each of these you can review what your rules do. They should all be very similar, except they will each set Buzzy's direction to a different value.

Let's try our new game out.

Press the play button. Can you use the keyboard to control where Buzzy flies now? Remember, L is left, R is right, U is up, and D is down. Do all of the directions work?

After you have played for a little while press the stop button so that we can add more to our game.

If Buzzy flew off of the board, press Reset to get him back.

Let's save our work.

*Go to the Hands menu in the top left corner, and choose **Save**.*

Please write down what time it is now _________________.

Collisions

We can make this game more interesting by making Buzzy do something besides fly around. He can collect nectar from the flowers. Each flower has a property to keep track of how much nectar it has left, and Buzzy can have a property to keep track of how much nectar he has collected.

Make sure you have clicked the Stop button.

Add a `Nectar` *property Buzzy's card.*

Buzzy has not collected any nectar yet, so leave the value set to `0`.

What if we wanted to make something special happen whenever Buzzy flies up to a flower? We can tell Handy to take some nectar from the flower and give it to Buzzy.

*Start a **new rule** in Handy's thought bubble.*

When one card touches another card on the game board, the objects have a **collision**. A collision is an event that Handy can look out for. If we want to tell Handy to watch for when Buzzy is in a collision, we tell Handy to do something `when Buzzy collides`.

Make the new rule start with: `When Buzzy collides into any flower`

What should happen when Buzzy collides with a flower?

Tell Handy to do these things:

```
subtract 1 from the flower's Nectar
add 1 to Buzzy's Nectar
beep
```

This tells Handy to decrease the flower's nectar by one, and increase Buzzy's nectar by one. It also asks Handy to beep so we will know each time a collision has happened.

Now, let's test this new rule.

Press the play button, and make Buzzy fly into some of the flowers a few times. Do you hear a beep each time Buzzy collides into a flower?

*Press the stop button, **but do not press Reset**. Look at the front of Buzzy, and see how much nectar he has collected.* He started with zero. Does he have some nectar now?

Look at the flowers to see how much he took from them. The all started with 25. The ones he collided into should have less than 25.

Let's save our work.

*Go to the Hands menu in the top left corner, and choose **Save**.*

Please write down what time it is now ________________.

Testing Your Ideas

When you put rules into Handy's thought bubble, Handy remembers them but he does not perform the actions in the rule right away. He waits until you press the Play button and then if he see an event that matches the rule he will do the actions.

Sometimes you might like to ask Handy to try something for you immediately, instead of making a rule and then waiting for him to see the rule's event. You can use the ***Testing Window*** to ask Handy questions and get his answers right away.

Let's open the Testing Window. Above Handy is a ***Programming*** menu.

*Choose **Open Testing Window** from the **Programming** menu.*

The Testing Window should be familiar because it is similar to Handy's thought bubble. But the things you type here are not put into Handy's thought bubble. Instead, he will do what you ask *one time only* when you push the ***Test It Now*** button.

*Let's try it. Let's ask Handy to do an easy math problem. Type "`1+1`" into the top right of the Testing Window and press **Test It Now.***

Did you see the number 2 appear in the bottom window? That is Handy telling you the answer. Handy can do harder math problems, and lots of other things.

Go ahead and ask Handy to do a few things.

More about Lists

Remember the way lists are written? Here is a list:

```
apple, pear, orange
```

Handy can also tell us information about a list, if we ask using words he understands. Sometimes these words look funny because they are all squished together without any spaces.

Let's look at an example.

```
FirstItem in apple, pear, orange
```

This asks Handy to tell us the first item in the list. Can you guess what Handy will tell us? The answer is `apple`.

Try it. Type `FirstItem in apple, pear, orange` *in the Testing Window and press and press **Test It Now**.*

Did Handy say `apple` in the bottom window?

Handy can work with the lists that are stored in properties of cards. If we want to get the list of all of the flowers, we can just type `Garden’s flowerList.`

Type `Garden’s flowerList` *in the Testing Window and press* ***Test It Now****. Handy gives us what’s in the* `flowerList` *property of the card* `Garden`*.*

Since we have put the names of all of the flowers into this property, it is an easy way to refer to all of them. Of course, it is up to us to make sure that the `flowerList` property of `Garden` always has the correct information in it. If we add more flowers to our game, we have to add them to this property too, or Handy won’t have them in the list of flowers.

Asking Handy to Look for Information

We can ask Handy to look through the cards and search for information about them. Let’s make a list of how much nectar each flower has. To do this we have to put together a few pieces. We will ask Handy to find all the flowers and look into the `nectar` property of each one.

Type `nectar of Garden’s flowerList` *into the Testing Window and see what Handy replies.*

Did you see a list of numbers in the bottom window? Each of these numbers came from the `nectar` property of one of the flowers.

Let’s ask Handy to show us which flower has the *least amount of nectar left*.

Handy understands a way to give us the card with the least value in a certain property. The outline for this question is:

`CardWithLeast` ***`property`*** `of` ***`cards`***

We have to fill in two pieces, which **property** Handy should look in, and which **cards** he should look at.

In this case, we would like handy to look in the `nectar` property, and the cards we want him to look at are `(Garden’s flowerList)`. So we can say:

`CardWithLeast` **`nectar`** `of` **`(Garden’s flowerList).`**

The parenthesis around (Garden’s flowerList) are necessary. It is best to be in the habit of always putting parenthesis around lists like (Garden’s flowerList) to make sure Handy will understand correctly.

Type `CardWithLeast nectar of (Garden’s flowerList)` *into the Testing Window to see what happens*.

If there is a tie, Handy will answer with a list of the flowers that have the least amount of nectar.

Handy also knows how to find the card with the greatest value in a certain property. The word Handy understands for that is: `CardWithGreatest.`

The Build Menu

At the top of the Testing Window there is a **Build** menu. This menu always changes to show you the words Handy understands at the spot where you’re typing. If you pick a word from this menu, it is the same as typing it. This could save you some work. For example, you can avoid typing long words like `CardWithLeast`. `CardWithLeast` is listed under the category **List Operators** in the Build menu.

There is also a Build menu in Handy's Thought Bubble. Using the Build menu is optional. You can use the keyboard to type the easier words, or all of them if you want to.

Please write down what time it is now _________________.

Displaying Answers on the Game Board

Now that we can get such great information from Handy, we should find a way to display it for everyone to see. We can create a card to keep track of which flower currently has the least nectar.

Close the Testing Window and create a new card. Give it the name `leastFlower`.

Create a `back` *property for the leastFlower card. It's ok to leave it set to zero.*

Move the leastFlower card onto the game board and flip it over. Right now, you should see the zero that's in the back property of the card.

A minute ago, Handy told us which flower has the least nectar in the Testing Window. But the answer could change while the game is running and Buzzy is taking nectar from the flowers. We would like Handy to keep us informed as soon as the answer changes. So we have to put the command into a rule. If we want Handy to check a rule all of the time, the event we want him to be on the lookout for is `when anything happens`.

Open Handy's Thought Bubble.

Use the New button to make a new rule.

Type `when anything happens` *for the event. This way Handy will do the action* ***all the time*** *when anything happens on the game board.*

We know we want Handy to figure out the `CardWithLeast nectar of (Garden's flowerList)`. We would like him to put the answer into the back property of the leastFlower card. To do this, we will ask him to:

```
     set leastFlower's back to
          CardWithLeast nectar of (Garden's flowerList)
```

Put that inside your new rule.

The rule should look like this:

```
when anything happens
     set leastFlower's back to
          CardWithLeast nectar of (Garden's flowerList)
end when
```

Press Check, to make sure the new rule is correct. If it is, close Handy's Thought Bubble.

Press Play to see what happens. Did Handy change the back of leastFlower to tell us which card or cards have the least nectar?

Have Buzzy land on a few flowers and watch what happens to the flower with least value. Did it change at all?

Press the stop button when you are finished.

Let's save our work.
*Go to the Hands menu in the top left corner, and choose **Save**.*

Please write down what time it is now ________________.

Adding up lists of numbers

What if we were going to create more bees to gather honey with Buzzy. We would have to make sure that there is enough nectar to go around. Handy can help us figure out how much nectar the flowers have altogether.

If we give Handy a list of numbers, he can add them up for us.
Open the Testing Window, and type `sum 1,2,3`
Handy adds up the numbers.

Earlier we used `nectar of (Garden's flowerList)` to make a list of the nectar in all of the flowers. If we want Handy to sum up all of these values we can combine this with the sum command like this:

```
     sum the nectar of (Garden's flowerList)
```

Try that in the Testing Window.
When we ask this way, Handy adds up all of the nectar in all of the flowers.

Now let's make a card for Handy to put the answer in.
Close the Testing Window and make a card named `total`.
Create a `back` *property for the total card. It's ok to leave it set to zero.*
Move the total card onto the game board and flip it over. Right now, you should see the zero that's in the back property.

We want Handy to always update the total card have the correct total nectar. Do you remember what event we want Handy to watch for if we want him to check a rule all of the time? It is `when anything happens`. Since we already have a rule for `anything happens` we will add another instruction to it.
In Handy's Thought Bubble, add another instruction to the `when anything happens` *rule. The new instruction is*:

```
     set total's back to sum the nectar of (Garden's flowerList)
```

Now your `anything happens` rule should look something like this.

```
when anything happens
     set leastFlower's back to
          CardWithLeast nectar of (Garden's flowerList)
     set total's back to sum the nectar of (Garden's flowerList)
end when
```

Press Check to make sure Handy understands the rule.
Press Play and watch what happens when Buzzy takes nectar from the flowers.
Handy should update the `total` card to always show how much nectar the flowers have altogether.

Let's save our work.
*Go to the Hands menu in the top left corner, and choose **Save**.*

Please write down what time it is now ________________.

<u>Making Changes to lots of objects</u>

What if there isn't enough nectar for a large group of bees? Let's tell Handy to give ten more nectar to each of the flowers when we type the "n" key. To do this, we will use something we learned earlier:

- Remember when we were writing the rule for when Buzzy lands on a flower? We used `subtract 1 from the flower's nectar` to take some nectar from the flower. This time we would like to `add 10 to the flower's nectar`

One at a time, we will make Handy do this to each of the flowers in (Garden's flowerList). The command to do that is `with`. The outline for the `with` command is:

```
with list calling each name
     do something to name
end when
```

1) The list we would like to use is **`(Garden's flowerList).`**
2) We would like to call each of them **`the flower`**.
3) The command to do to each one is **`add 10 to the flower's nectar.`**

Let's put this all together to accomplish our goal. We can ask Handy to:

```
with (Garden's flowerList) calling each the flower
     add 10 to the flower's nectar
end with
```

In Handy's Thought Bubble, create a new rule to do this. Handy will go to every flower and add 10 to its nectar property.

Press Check, to make sure Handy understands the rule.

Press Play, and try it out by pressing the N key.

Did you see the total nectar increase by 30 each time you pressed the N key? This is because there are 3 flowers, and each one gets 10 added to its nectar.

Let's save our work.

*Go to the Hands menu in the top left corner, and choose **Save**.*

Please write down what time it is now ________________.

Congratulations! You have completed the HANDS Tutorial. You were able to make a fun world with bees and flowers, and hopefully, you learned a lot about HANDS along the way.

Student Number________________

Great job! Now that you have learned so much about HANDS, you are ready to try to do some more things on your own.

Here is a new game similar to the one you created. Buzzy went back to the hive and told all of the bees about the wonderful flowers he found. Now lots of Buzzy's friends have come to gather nectar with him. To help us keep track of Buzzy, he is bigger than all the other bees. You can still control Buzzy with the U, D, L and R keys.

All of the bees now have a special property so Handy knows they are bees. This is the property named `kind` with the value `bee`. You can see this for yourself on each bee card. Handy knows some rules to make the bees fly around and collect nectar on their own. Also, the `Garden` card has a new property named `beeList` listing all of the bees in the game.

Can you add some things to this new game? You can refer to the tutorial if you need some hints.

Please write down what time it is now ________________.

1. Display the name of the bee that collected the greatest amount of nectar.

A card named bestBee has been created for this problem. Have Handy check which bee has the greatest amount of nectar, and put the answer into the back property of bestBee. Handy should always update this information while the game is running. This means he should do it `when anything happens`.

Hint: It may be useful to review page 11 of the tutorial, in the section "Asking Handy to Look for Information".

Run your game to check if it works. The first set of question-marks (???) should be replaced by the name of the bee with the greatest amount of nectar.
Go to the Hands menu in the top left corner, and choose **Save**.
Please write down what time it is when you finish this problem ________________.

2. Make all of the bees stop flying when the S key is typed.

You will need to set their speed to 0.

Hint: It may be useful to review page 7 of the tutorial, in the section "Events".

Run your game to check if it works. All of the bees should stop when you press the S key.
Go to the Hands menu in the top left corner, and choose **Save**.
Please write down what time it is when you finish this problem ________________.

3. Let all of the bees fly again when the G key is typed.

They should fly at the speed of 1.

Run your game to check if it works. All of the bees should go when you press the G key.
Go to the Hands menu in the top left corner, and choose **Save**.
Please write down what time it is when you finish this problem ________________.

4. Display how much nectar all of the bees have collected.
A card named beeTotal has been created for this problem. Tell Handy to add up how much nectar all the bees have, and put the answer into the back property of beeTotal. Handy should update this as often as possible.

Hint: You may find useful information on page 13 of the tutorial, in the section “Adding up lists of numbers”.

Run your game to check if it works. The third set of question-marks (???) should be replaced by the total amount of nectar collected by all of the bees.
Go to the Hands menu in the top left corner, and choose **Save**.
Please write down what time it is when you finish this problem _________________.

5. Add another bee to the world.
Copy one of the existing bees and name it with your best friend’s name.

Hint: Look near the top of page 5 in the tutorial if you forgot how to copy cards.

Run your game to check if it works. Your new bee should stop when the S key is hit, and go again when the G key is hit. If your new bee does not stop and go, try to figure out why and fix it.
Go to the Hands menu in the top left corner, and choose **Save**.
Please write down what time it is when you finish this problem _________________.

That’s all. Thanks for your help!

BONUS PROBLEM:
If you have extra time, you can try this bonus problem.

6. Display how much nectar the best bee has.
A card named mostNectar has been created for this problem. Tell Handy to figure out how much nectar the best bee has, and put the answer into the back property of mostNectar. Handy should update this as often as possible.

Hint: You will need to use your answer to problem 1 as part of your answer here.

Run your game to check if it works. The second set of question-marks (???) should be replaced by the amount of nectar collected by the best bee.
Go to the Hands menu in the top left corner, and choose **Save**.
Please write down what time it is when you finish this problem _________________.

```
beeTotal x:406 y:60 back:"???";
beeTotalSign x:200 y:60 back:"All the bees have collected:";
bestBee x:406 y:20 back:"???";
bestBeeSign x:200 y:20 back:"The bee with the most nectar is:";
Bumbles x:530 y:60 kind:bee back:bumbleb.gif nectar:5 speed:1 direction:270;
Bumbles2 x:465 y:35 kind:bee back:bumbleb.gif nectar:5 speed:1 direction:270;
Buzzy x:575 y:152 kind:bee back:bee.gif nectar:0 speed:3 direction:270;
Buzzy2 x:677 y:102 kind:bee back:bumbleb.gif nectar:6 speed:1 direction:270;
Fuzzy x:450 y:120 kind:bee back:bumbleb.gif nectar:3 speed:1 direction:270;
Fuzzy2 x:580 y:290 kind:bee back:bumbleb.gif nectar:7 speed:1 direction:270;
Garden x:175 y:576 beeList:Bumbles, Bumbles2, Buzzy, Buzzy2, Fuzzy, Fuzzy2, Honey,
Honey2, Killer, Killer2, Stripes, Stripes2 flowerList:Lily, Lily2, Rose, Rose2, Sunflow-
er;
Honey x:280 y:230 kind:bee back:bumbleb.gif nectar:7 speed:1 direction:270;
Honey2 x:490 y:260 kind:bee back:bumbleb.gif nectar:1 speed:1 direction:270;
Killer x:650 y:90 kind:bee back:bumbleb.gif nectar:0 speed:1 direction:270;
Killer2 x:205 y:108 kind:bee back:bumbleb.gif nectar:0 speed:1 direction:270;
Lily x:318 y:329 kind:flower back:lily.gif nectar:100;
Lily2 x:675 y:308 kind:flower back:lily2.gif nectar:100;
mostNectar x:406 y:40 back:"???";
mostNectarSign x:200 y:40 back:"He has this much nectar:";
Rose x:205 y:319 kind:flower back:rose.gif nectar:100;
Rose2 x:465 y:328 kind:flower back:rose2.gif nectar:100;
Stripes x:300 y:150 kind:bee back:bumbleb.gif nectar:8 speed:1 direction:270;
Stripes2 x:403 y:202 kind:bee back:bumbleb.gif nectar:3 speed:1 direction:270;
Sunflower x:555 y:330 kind:flower back:sunflower.gif nectar:100;
when any bee collides into any flower
       subtract 1 from flower's nectar
       add 1 to bee's nectar
       beep
end when
when D is typed
       set buzzy's direction to 270
       set buzzy's speed to 3
end when
when L is typed
       set buzzy's direction to 180
       set buzzy's speed to 3
end when
when program starts
       with EveryBee's list calling each b
              set direction of b to random 240 to 300
       end with
end when
when R is typed
       set buzzy's direction to 0
       set buzzy's speed to 3
end when
when U is typed
       set buzzy's direction to 90
       set buzzy's speed to 3
end when
```