

# METHODOLOGY

## for Uncovering **MOTION AFFORDANCE**

### Chujit Jeamsinkul & Sharon Poggenpohl in Interactive Media

INTERACTIVE MEDIA allows the user to have control over navigation and interactivity with the information. The nature of interactive media is dynamic and changes through time. To support this dynamic change, knowledge of how to communicate information efficiently beyond static representation needs exploration.

Motion is a key element in interactive environments. Motion helps the user to perceive a change of state. The characteristics and capabilities of motion demonstrate its potential benefit to interaction, but there is very little guidance available regarding when and how to use motion in interactive media.

Though Baecker and Small performed research concerning motion's utility in interface, questions still remain: "How do we design such animation so that they are clear and comprehensible, attractive and appealing? How do we prevent animation from being too complex to be effective? Such questions can be answered only through the extensive development of prototypes and through user testing" (Baecker and Small, 1990). By looking at motion systematically with regard to how users understand it, knowledge of how to use motion effectively in interactive media can be revealed. This paper examines the process of designing an experimental situation in which the meaning of motion can be revealed. Because the experiment was executed, data is analyzed, results are discussed and further developments are identified.

## OVERVIEW

Motion is fundamental for survival. Humans perceive and live in motion in space and time. We are creatures with both body and mind: our perception and emotion is bio-basic. Neuroscience is uncovering the physiology of the active mind (Damasio, 1999), resulting in new theories of consciousness and emotion. Western philosophy and linguistics (Lakoff & Johnson, 1999) are reuniting mind and body into a unitary entity that interacts with and interprets the world. "Emotion, as the word indicates, is about movement, about externalized behavior, about certain orchestrations of reactions to a given cause, within a given environment. Emotions are part of the bio-regulatory devices with which we come equipped to survive. That is why Darwin was able to catalog the emotional expressions of so many species and find consistency in those expressions and that is why, in different parts of the world and across different cultures, emotions are so easily recognized. That makes cross-cultural relations possible and that allows for art and literature, music and film, to cross frontiers." (Damasio, 1999) It is from these perspectives that the following work emerges. What we perceive, feel and understand about motion in the real world is emblematic of how we process and interact with information on the screen. Because our perception of motion and its affordances are bio-basic, a common set of motion meaning on screen is plausible to explore.

The focus of this research concentrates on the experimental method to uncover the meaning of motion in terms of how users perceive, feel, understand and respond to various types of motion in interactive media. Types of motion are systematically identified in a motion structure in order to develop a variable framework for creating an experiment to gather information from users. The experiment is designed to capture three types of motion meaning: interpretative meaning, emotional response and motion affordance in interaction functions. Quantitative methods are used to analyze patterns and relationships of motion and its meaning. Two measurement scales; nominal measurement scales and interval measurement scales are applied in this experiment. The nominal measurement takes the form of a checklist. The user chooses one answer from a set of multiple choices. Semantic Differential Scales (Osgood, Suci and Tannenbaum, 1957) are used to measure the emotional meanings users ascribe to a specific type of motion at the

interval level. The analysis from these relationships recommends when and how to use motion effectively in interactive media.


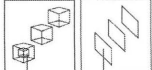

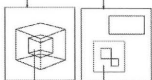
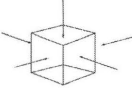

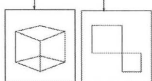


The findings of these common meaning dimensions for each discrete motion can generalize to use in many ways depending on what function the motion represents. For instance, designing for a 'warning' and suggesting a cue for 'next' require different degrees of attraction and attention. Psychologically, attracting attention with a degree of annoyance would urge the user to do something more than attracting attention with pleasure, which is better for cueing. This research supports designers' need for effective, comprehensible and natural ways of employing motion to enhance and facilitate the user's activities while navigating through interactive media.

## REVIEW OF LITERATURE

Based on the earlier study (Jeamsinkul and Poggenpohl, 2001), five aspects of motion from five disciplines, psychology, neuroscience, film, computer animation and design, are included in this study. Psychological research focuses on motion phenomenon to understand why and how we see motion (Epstein & Sheena, 1995; Gibson, 1979; Hoffman, 1998). Neuroscience research focuses on motion-motor processing to understand what part of the brain or nervous system responds to motion (Berthoz, 2000). Film research focuses on how to convey meaning and elicit viewers' feeling through manipulating time, camera technique, editing technique, lighting and so on (Chandler, 1994). Computer animation research focuses on motion structure at an operational level in order to simulate or imitate real world motion (Owen, 1986; Thalmann, 1985; Ullman, 1979). Existing design research focuses on application and operation of motion in terms of applying knowledge of computer animation to design principles on screen (Sivasankaran and Owen, 1992; Nishimura and Sato, 1985).

Even though, motion has been researched in many areas, knowledge of motion cognition or how humans understand and respond to certain types of motion is not well developed. Questions remain: What is the relationship of motion representation and control structure to motion perception? Do people interpret motion in similar ways? Existing motion research is either very specific or abstract and does not

## UNDERSTANDING OF MOTION

| Object(s)   |  | Behavior(s)  |        |                                      | Space (Environment)                                       |   |   |
|---|--|--|--------|--------------------------------------|---|---|---|
| Quantity  | Quality  | Transposition  | or/and | Transformation + Time (in operation) | Boundary  | Perspective   |   |
| 1 Object<br>               | Size<br>Shape<br>Texture<br>Rigidity<br>(hardness/softness)  | Movement Direction<br>- X horizontal (left-right)<br>- Y vertical (up-down)<br>- Z depth<br>(in-out/zoom)  |        | Scale<br><br>Distort                 | Speed<br><br>Repetition                                   | Universe to Individual<br><br> | View point change<br>Object not change  |
| 2 Objects<br>              | Viscosity<br>(resistance to flow)<br>Cohesiveness<br>(strength-resistance to breaking)                                     | Rotate<br>- X (Tilt)<br>- Y (Swivel)<br>- Z (Clockwise-Counter Clockwise)  |        | Blur<br><br>Change color             | Duration<br><br>Rhythm<br>= Speed + Repetition + Duration |                                |  |
| Group of Objects<br>       | Elasticity<br>(regain the previous shape after deformation)<br>Plasticity<br>(hold the subsequent shape after deformation) |  |        | Fade<br><br>Brightness               | Appearance/Disappearance is a part of duration            |                                | <b>Ground</b>   |
| 2 Groups of Objects<br>    | Color<br>Opacity<br>(semi-transparent, translucent)<br>Luminance<br>Illumination   | <i>Note: Combination of transposition or/and transformation with time generate many other characters and behaviors.</i>                              |        |                                      |   |   |   |
| Many Groups of Objects<br> |  | <i>For example:<br/>Change in brightness + Appearance/Disappearance + Duration = Flash<br/>Rotate + Scale + Speed = Movement along Tunnel, Depth</i> |        |                                      |   |   | Background<br>Non-focus objects   |

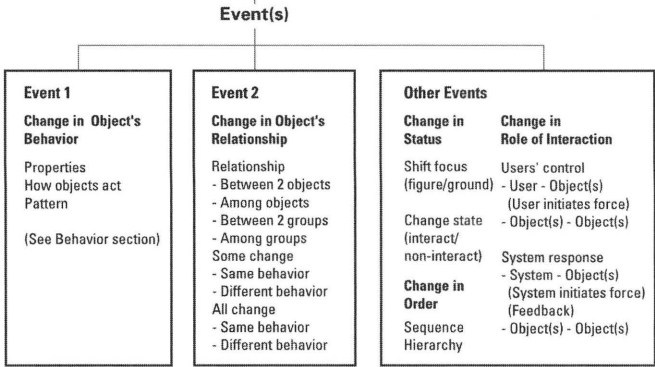
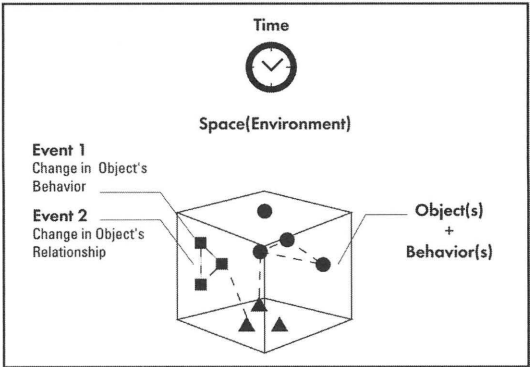


FIGURE 1  
Motion Structure  
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answer the operational questions regarding motion use and interpretation in interactive media that design needs answered.

The Motion Structure (figure 1) was generated from analyzing and synthesizing literature related to motion. Motion occurs when there is a change of behavior of object(s) in space through time. Thus, motion on screen is composed of four crucial components: object(s), behavior(s), space and time. These four components generate different types of events as seen in figure 1.

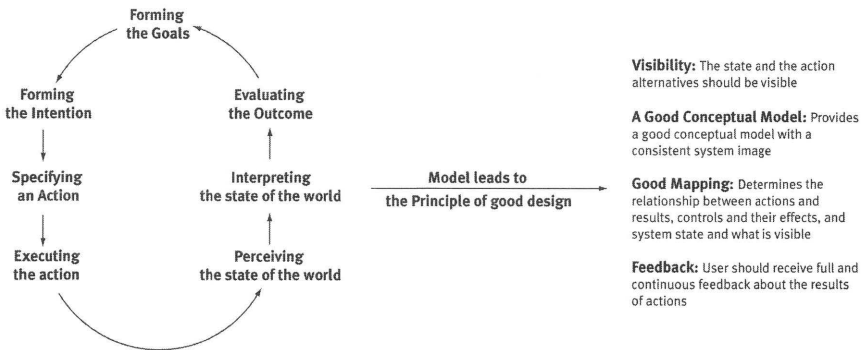
**MOTION  
STRUCTURE**

Interaction occurs in a feedback loop between human and machine. In this research, 'interaction functions' means functions that the system should provide users in order to enhance their efficiency of interaction. Interaction functions derive from various levels and viewpoints in human-computer interaction (HCI). To understand what interaction functions are, user's stages in interacting with the media are analyzed. Donald Norman identified seven stages of action in *The Psychology of Everyday Things*, 1988 as in the following diagram (figure 2).

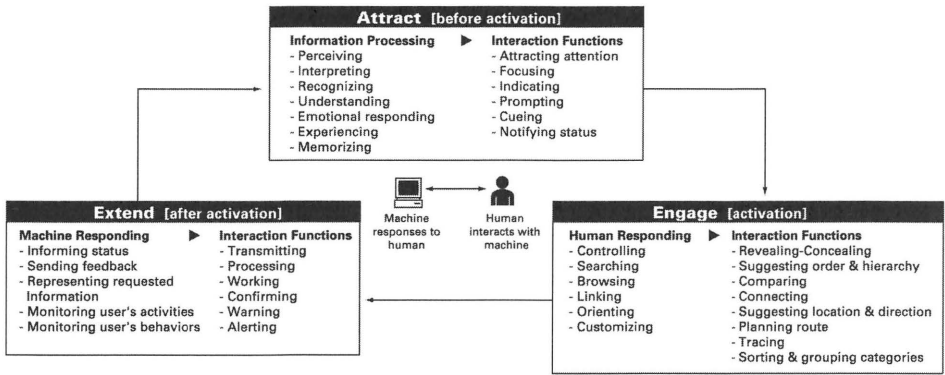
**UNDERSTANDING  
INTERACTION  
IN INTERACTIVE  
MEDIA**

Basically, these stages could group into three fundamental stages as: Before Executing Action (attraction), Executing Action (engagement) and After Executing Action (extension) as shown in figure 3. To define the function of a specific interaction is to look at what is happening in each state. Attracting attention is the beginning of the process. At this point, the user processes information before acting. Then the user responds to the information by acting. After the user's responses are sent to the machine, the machine sends back user feedback, status and cues. All these behaviors lead to interaction functions as specified in figure 3.

**MAPPING  
BETWEEN  
MOTION  
STRUCTURE AND  
INTERACTION**



**FIGURE 2**  
Link between user's stages in interacting with media and principle of good interaction design, adapted from Norman, 1988



**FIGURE 3**  
Interaction Model

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In figure 3 interaction functions are outlined from a human perspective. The experiment is constructed in order to find the motion meaning that will link the relationship between types of motion and interaction functions. (The experiment is explained in detail later in the methodology section.)

### SCOPE OF RESEARCH

#### RESEARCH GOAL

The object of this research is to analyze the meaning and affordance of motion in interactive media by testing variables of motion as they affect perceivers. Inevitably motion expresses itself through its own language. It is used ubiquitously in a variety of interactive applications, making communication through motion a crucial element to convey meanings in an effective way. Thus, this research generates a methodology for uncovering motion language and identifying motion affordances in interactive media.

#### RESEARCH QUESTIONS

- > What are the affordances of motion in interaction?  
And what attributes do people associate with them in terms of the effects (meaning) of each type of motion to users?
- > Do users have common understandings of motion?

## METHODOLOGY

The purpose of this research is to uncover the fundamental meaning of motion and its relationships by understanding how users perceive, feel, understand and respond to various types of motion in interactive media. To accomplish this purpose, the following considerations and procedures were developed with regard to the experimental design. First, the number of motion variables had to be controlled. (Possibilities for 427 motion variable combinations were identified.) After identifying the motion variables for study, the second step was to create the stimuli for them. (The details are described in the later section.) The third step was developing questions. The nature of interaction in interactive media is spontaneous action, response and turn taking. Developing questions that capture the user's intuitive response to motion was crucial. Furthermore, the notion of motion meaning itself has many perspectives and can be descriptive meaning, interpretative meaning, expressive meaning and purposeful meaning. The experiment has multiple questions to capture various notions of meaning. The fourth step is developing choices for each question. All choices depend on the nature of motion variables. With all material in hand, the last step was creating the experiment and its instruction as a pre-test, the experiment prototype was tried with small number of participants to identify problems in the experimental design. This also facilitates improvement of questions and choices. (The pilot study of this research was published in the proceedings of Asian Design Conference 2001.) The process of designing this experiment is explained in the following sections.

Motion occurs when there is a change of behavior of object(s) in space through time. Thus, motion on screen is composed of four crucial components: object(s), behavior(s), space and time. By altering variables in these four components, numerous different types of events, depending on which variable combinations are selected (see table 1), can be generated.

Setting up an experiment to test all possible motion events at the same time would be impossibly large. Therefore, this research focuses on the most fundamental motion path by concentrating on motion behavior variables only. Nine types of motion behaviors are presented: 6 from transposition (Move X, Y, Z and

**SELECTING  
MOTION  
VARIABLES  
TO TEST**

Rotate X, Y, Z) and 3 from transformation (Blur, Brightness and Opacity). Direction is another significant variable that causes motion behavior to signify different meanings. This experiment applies 2 directions to each motion: forward (d1) and backward (d2). Speed is also a very important variable that could alter perceivers' emotional response. Obviously, fast movement may be perceived as more exciting than slow movement. If we incorporate 3 levels of speed (fast, medium and slow) in this experiment, the number of stimuli would be 54 movies (see table 1 in study #2).

| Study | Object   |                    |                   | Behavior Variables <sup>1</sup> |               |       | Time Variables |       |            | Direction |   |   | Motion Movies |
|-------|----------|--------------------|-------------------|---------------------------------|---------------|-------|----------------|-------|------------|-----------|---|---|---------------|
|       | 1 object | More than 1 Object | Groups of Objects | 1 variable                      | Mix Variables |       |                | Speed | Repetition | Duration  | → | ← |               |
|       |          |                    |                   |                                 | TP+TP         | TF+TF | TP+TF          |       |            |           |   |   |               |
| 1     | ■        |                    |                   | ■                               |               |       |                |       |            |           | ■ | ■ | 18            |
| 2     | ■        |                    |                   | ■                               |               |       |                | ■     |            |           | ■ | ■ | 54            |
| 3     | ■        |                    |                   | ■                               |               |       |                |       | ■          |           | ■ | ■ | 18            |
| 4     | ■        |                    |                   | ■                               |               |       |                |       |            | ■         | ■ | ■ | 54            |
| 5     | ■        |                    |                   |                                 | ■             |       |                |       |            |           | ■ |   | 15            |
| 6     | ■        |                    |                   |                                 | ■             |       |                |       |            |           | ■ | ■ | 15            |
| 7     | ■        |                    |                   |                                 |               | ■     |                |       |            |           | ■ |   | 3             |
| 8     | ■        |                    |                   |                                 |               | ■     |                |       |            |           | ■ | ■ | 3             |
| 9     | ■        |                    |                   |                                 |               |       | ■              |       |            |           | ■ |   | 18            |
| 10    |          | ■                  |                   | ■                               |               |       |                |       |            |           | ■ |   | 9             |
| 11    |          | ■                  |                   | ■                               |               |       |                |       |            |           |   | ■ | 9             |
| 12    |          |                    | ■                 | ■                               |               |       |                | ■     |            |           | ■ |   | 27            |
| ...   |          |                    |                   |                                 |               |       |                |       |            |           |   |   | ...           |

**TABLE 1**  
Overview of Motion Variables

**TP = Transposition**  
Move X, Move Y, Rotate X, Rotate Y, Rotate Z  
**TF = Transformation:**  
Blur, Brightness, Opacity

This considerable amount of stimuli could cause an habituation problem as occurred in the pilot study when participants did the experiment with 36 movies. For this reason, speed requires a future experiment. Therefore in this experiment, time variables, the number of objects and environmental space is fixed. These conditions reduce the stimuli in this experiment to one object and one behavior variable in two directions leading to a total of 18 motion movies for this experiment.

**CREATING STIMULI**

The stimuli need to be as neutral as possible in terms of color and shape, thus meanings attached to those factors will not interfere with the pure meaning of motion itself. Gray is the appropriate color to apply, as it is a neutral color. The simplicity of abstract forms such as geometric shapes: triangle, circle and

square are taken into account. Triangles imply direction, circles in plain gray are not noticeable when rotated in Z direction. Compared to other geometric forms, squares are a good choice for the stimuli, as they are directionless and will deform in space and motion. The stimuli consist of 18 movies created by animating a gray square in a black environment (*see figure 4*). To focus on the meaning of each motion behavior, control of time variables are required for all movies. Every short motion clip has the same speed, one repetition and a 2-second duration.

To support the process of uncovering motion meaning, three types of questions are developed. Sensory question, “What is the square doing?” is to capture descriptive and interpretative meaning. Feeling question, “How do you feel about the movie?” is to elicit expressive meaning or emotional responses. Behavioral question, “What activities does the movies remind you of?” is to link to purposeful meaning, in this case interaction functions.

The format for answer for questions could be closed or open. Pilot study results suggested pro and con for both formats. An open answer allows participants to use their own words. This is a direct answer from participants’ point of view. However, an open answer causes participants spend a long time thinking about what they should answer, which does not match the research purpose in terms of capturing an immediate intuitive response. Moreover, similar answers need subjective interpretation to determine the level of agreement. On the other hand, a closed answer provides participants with a limited number of choices from which to choose. These choices might not cover every meaning participants have in mind, however, these choices are strongly related to the research objective. This format also does not require a subjective interpretation, consequently it generates a clear degree of agreement.

By using an open question in the pilot study, the answers capture possible choices that might have been ignored. Answers from the pilot study enriched consideration of the final language choices for the closed answers of the primary experiment.

## DEVELOPING QUESTIONS FOR EXPERIMENT

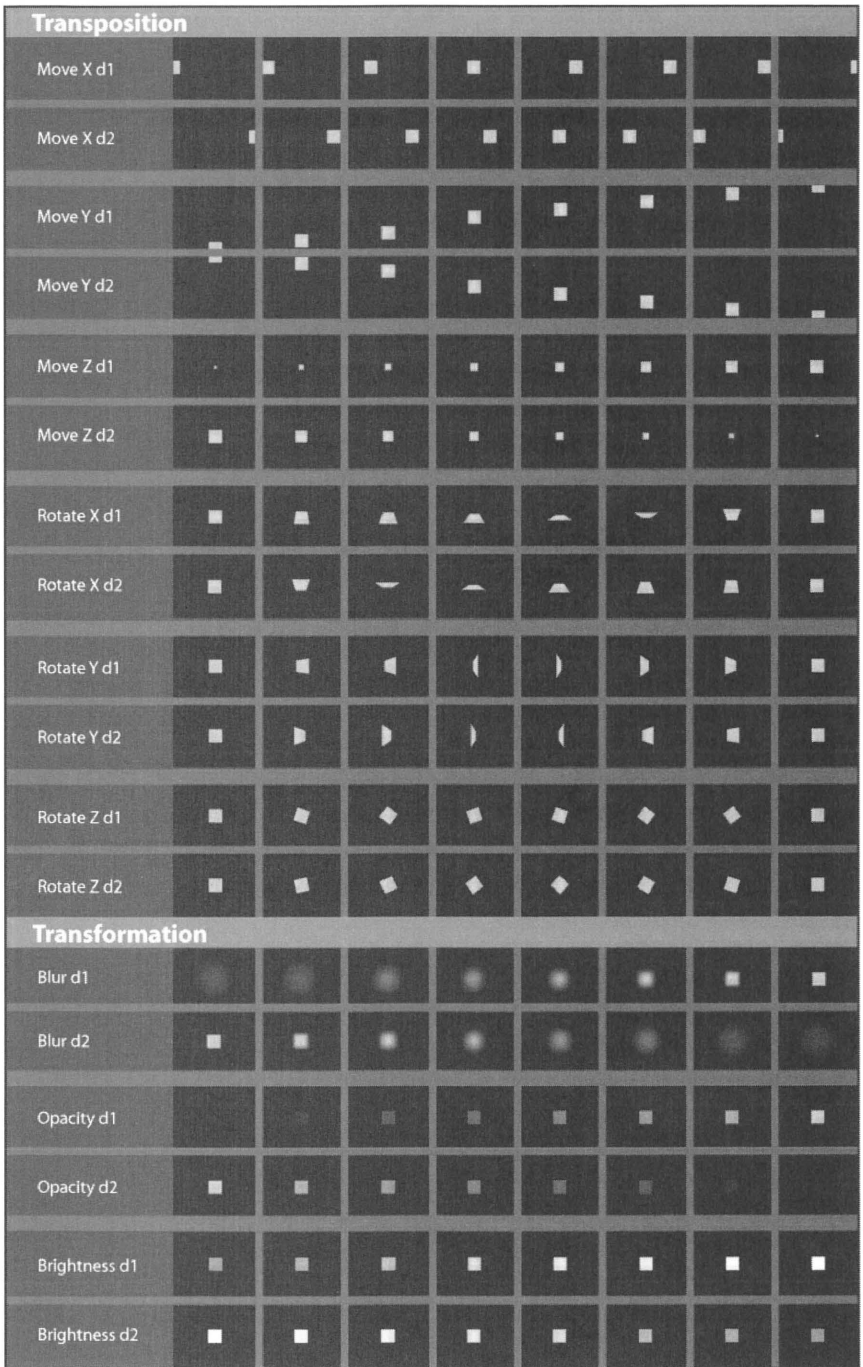


FIGURE 4  
Picture sequences  
of 18 movies

All movies in the experiment need the same answer selection to facilitate comparison. The following diagram (figure 5) is an overview of choices for each question. (The process of how to develop answer selection is explained in detail later.)

**Development of choices in question 1**

*What is the square doing?*

In question 1, choices came from analyzing all of the pilot study choices in 30 movies and choices that participants in the pilot study added categorizing in position map as shown in figure 6.

Most of the interpretative choices are more useful than descriptive choices in relation to interaction functions. Moreover those choices are general enough to apply to all movies. Therefore in the primary experiment, the choices are selected from the interpretative side. The potential choices in question 1 are; Advancing, Retracting, Increasing, Decreasing, Forwarding, Reversing, Revealing, Concealing, Focusing, Losing focus, Emphasizing and De-emphasizing.

**Development of emotional categories in question 2**

*How do you feel about the movie?*

The diagram in figure 5 presents three types of emotions based on dimensional approaches to emotion (Lang, 1995; Osgood, Suci and Tannenbaum, 1957; Russell and Mehrabian, 1977). **Arousal** and **hedonic valence** are the two most commonly cited emotion dimensions and the third, less frequently used dimension, is **dominance**. The dimension of **autonomic arousal** is characterized by a continuous response ranging from energized, excited and alert to calm, drowsy or peaceful. The **valence** dimension is a continuous range of affective response extending from pleasant or positive valence at one pole, to unpleasant or negative valence at the other (Detenber et al, 1998). These two dimensions, valence and arousal,

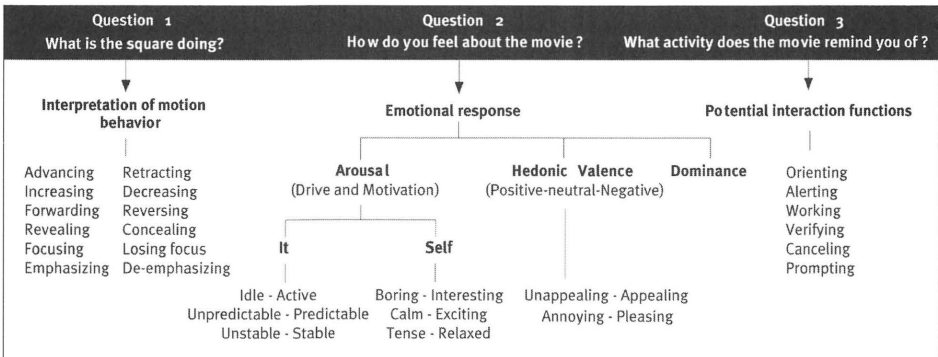


FIGURE 5  
Overview of choices  
for each question



**TABLE 2**  
Interaction Function  
Analysis

| FUNDAMENTAL INTERACTION FUNCTIONS (general functions, which are applied to any interaction design) |   |  |   |
|--|---|--|---|
| <b>PERCEIVING</b>  | <b>PROMPTING/CUEING</b>                                   | <b>VERIFYING/CONFIRMING</b>  | <b>ORIENTING</b>  |
| Preview<br>Just Looking<br>Focus   | Hinting<br>Allow Typing Ahead<br>Show the Format Required | Shield<br>Think Twice  | Navigating Spaces<br>List Browser<br>Continuous Filter<br>Automatic Mode Switching<br>The MVC Architecture<br>Contextual Menu<br>Helping Hands (Toggle)<br>Softkeys |
| <b>WORKING</b>   | <b>CANCELLING</b>   | <b>ALERTING/ALARMING</b>   |   |
| Identify Progress<br>Show Computer is Thinking   | Undo<br>Emergency Exit                                    | Give a Warning   |   |
| SPECIFIC INTERACTION FUNCTIONS (specific functions, which depended on content of the project)      |   |  |   |
| <b>CUSTOMIZING</b>   | <b>SIGNIFYING AREA</b>                                    | <b>REPRESENTING AFFORDANCE</b>   |   |
| Preference<br>Managing Favourites<br>Setting Attributes<br>Wizard                                  | Command Area<br>Container Navigation<br>Grid Layout       | Like in the Real World...<br>Change Mode Cursor<br>Unambiguous Format<br>Magnetism |   |

interaction functions can be identified in detail by looking at the available guidelines for interactive media such as hypertext system and software interface (Nielsen, 2000; Welie and Traetteberg, 2000; The Usability Group, 2001). Selected guidelines are categorized and the groups are named as interaction functions (*see table 2*).

In this experiment, the focus is on the fundamental interaction functions because these can generalize and apply to any kind of interaction design. The final list for the interaction function choices are Orienting, Alerting, Working, Verifying, Canceling and Prompting.

When all stimuli, experimental questions and supported choices are prepared, integrating and representing them to study participants is an essential step. Four main issues are: media selection, instruction for the experiment as a tutorial, order of stimuli (movies) and questions and method of capturing answers.

The result from this experiment will be used to generate motion knowledge for interactive media on screen, therefore setting up an experiment on a computer is appropriate. This research is a quantitative experiment. Collecting quantitative data requires many participants to produce stable results. Thus the prototype contains an integral tutorial requiring no supervision. The tutorial is interactive allow-

**CREATING  
EXPERIMENTAL  
PROTOTYPE**

ing the participant to become accustomed to the experimental process before answering the actual questions. Furthermore, the description in the tutorial provides the same information to every participant.

The order of the movies can affect the answers, because the participant might see relationships between movies when they are similar and in proximity. All movies are random ordered based on three rules: 1) no consecutive movie has the same motion behavior, even if it has a different direction; 2) the same direction of movement cannot follow each other; and 3) movies alternate with regard to type of movement, rotation and transformation. Interpretative meaning choices are considered as a sub-function of the interaction function choices. To avoid creating a relationship among answers, the emotional response question is segregated.

Coding script in Director plays a considerable role in making possible automatic capture of all answers to text files while the experiment is in progress. These files are ready to import to an analysis program such as Excel and SPSS. Auto capture reduces the time between experiment and analysis and removes errors in manual entry of data.

## RESEARCH PARTICIPANTS

One hundred participants from 16 countries participated in this experiment. Participant background was diverse with 42 Thais, 31 Americans, 5 Indians, 3 Chinese, 3 Indonesians, 3 Mexicans, 2 Brazilians, 2 Japanese, 2 Koreans, 1 Taiwan, 1 Canadian, 1 Columbian, 1 Pakistanis, 1 Hungarian, 1 Swiss and 1 Turk. Distribution of gender is in the proportion of female 61 and male 39. The age range of participants was from 15 to 55 years with the majority between 21–30 years. More than half the participants had much experience with computers (more than 5 years).

## EXPERIMENTAL PROCEDURE

Participants are provided with an interactive tutorial with a voice over describing all procedures step-by-step. This tutorial serves as a practice before the real experiment. It also requires the completion of a demographic survey (*see figure 7*) in the first page before advancing to the experiment section. The experiment asks individuals to watch a set of movies and answer questions. The entire experiment runs seamlessly

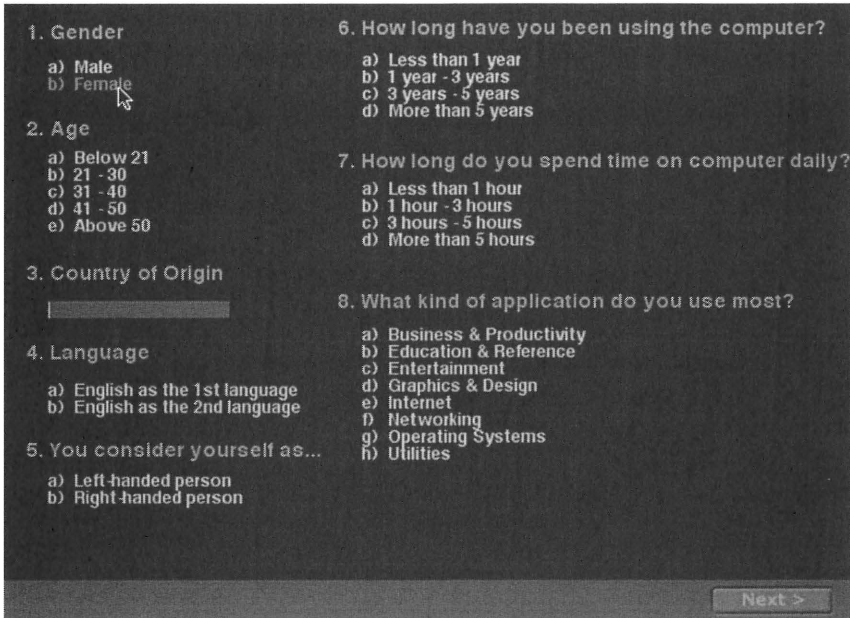


FIGURE 7  
Demographic  
data collection

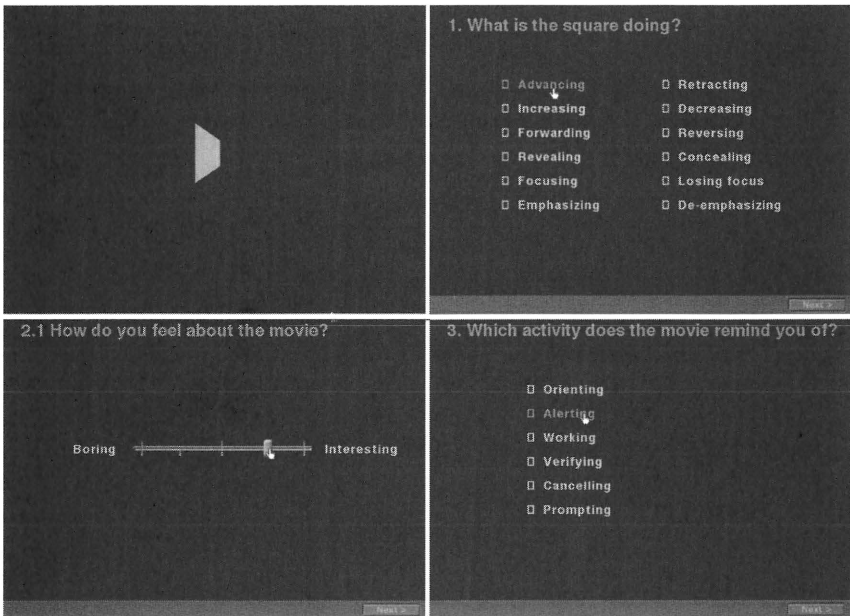


FIGURE 8  
Experiment format

on a laptop computer. Each movie lasts 2 seconds. After each movie, subjects are asked to select one answer from 12 choices in the first question, rate their emotional response to the movie just seen and select one answer from 6 choices in the last question (see *figure 8*). Subject's answers are captured directly to the computer. The entire experiment lasts between 15 to 20 minutes.

## RESULTS AND ANALYSIS

To analyze quantitative data, two types of statistical data analysis are possible: Descriptive and Inferential. Both are used.

**Descriptive statistical data analysis** summarizes an entire set of quantitative data, which describe the results from participants from the following perspectives:

- > Which movies have high agreement and low agreement in interpretative meaning, emotional response and interaction function
- > What are the similarities and differences among motion types
- > Which movies represent which choices most (in both meanings and functions)
- > Which movie has the most extreme emotional response in either a positive or negative way

**Inferential statistical data analysis** examines how likely difference is between groups and relationships between variables occurring by chance, which interpret results in the following inquiry:

- > Do culture, professional training such as designer/non-designer, computer experience, gender and age range influence the way participants respond to the meaning, emotion and function of motions?

There are two types of levels of measurement in the experimental results. The first is a nominal scale, which is derived from the participants' answers selected from multiple-choices in question 1: interpretative meanings and question 3: Interaction functions. All answers in question 1 and 3 were plotted into a matrix to analyze their pattern and the relationship among movies and choices. The second is an interval scale, which is derived from rating the semantic differential scale of emotional response categories. The mean of each emotional response category in each movie was plotted into semantic differential profiles to compare patterns among direction and motion types. The details follow.

### **Matrix Analysis of All Movies with All Choices**

From the experiment with 18 movies, a total of 43 bar graphs was generated. Thirty-six bar graphs (not shown): each set of 18 graphs from question 1 and question 3 display frequency counts for each choice. The answers for question 2 (emotional response) are analyzed in 7 categories: Boring-Interesting, Unpredictable-Predictable, Idle-Active, Annoying-Pleasing, Unstable-Stable, Calm-Exciting and Tense-Relaxing in a scale from -2 to 2. Zero represents a neutral response with -2 and 2 the extreme emotional responses. Rating scales in Q2 were translated into frequency counts and combine scale -2 and -1 together as well as combine scale 1 and 2. Then the numbers with the highest percentage of each selected choice were brought together and plotted in the matrix (*see table 3*) to analyze patterns and relationships of motion types and their meanings, emotional responses and functions.

From the results in all questions, the high numbers of frequently selected choices were plotted in the matrix (*see table 3*).

### **Insight from Matrix Analysis**

The levels of high agreement throughout the 3 questions vary. For instance, blur in both direction 1 and direction 2 have the highest agreement in interpretative meaning, while opacity d2 has the highest agreement in interaction function. Emotional response generates significantly high agreement when compared with interpretative meanings and interaction functions.

TABLE 3  
Matrix comparison  
of motion movies  
to meaning

|               | Interpretative Meanings |         |          |          |         |         |        |         |          |              |             |                | Interaction Functions |          |         |           |           |           | Emotional Responses |             |               |             |      |        |          |          |          |        |      |          |       |          |  |  |  |  |  |
|---------------|-------------------------|---------|----------|----------|---------|---------|--------|---------|----------|--------------|-------------|----------------|-----------------------|----------|---------|-----------|-----------|-----------|---------------------|-------------|---------------|-------------|------|--------|----------|----------|----------|--------|------|----------|-------|----------|--|--|--|--|--|
|               | Advance                 | Retract | Increase | Decrease | Forward | Reverse | Reveal | Conceal | Focusing | Losing focus | Emphasizing | De-emphasizing | Orienting             | Alerting | Working | Verifying | Canceling | Prompting | Boring              | Interesting | Unpredictable | Predictable | Idle | Active | Annoying | Pleasing | Unstable | Stable | Calm | Exciting | Tense | Relaxing |  |  |  |  |  |
| Move X d1     | 31                      |         |          |          | 44      |         |        |         |          |              |             |                | 36                    | 40       |         |           |           |           |                     |             |               | 67          | 80   | 60     |          |          |          |        |      |          |       |          |  |  |  |  |  |
| Move X d2     |                         | 23      |          |          |         | 40      |        |         |          |              |             |                | 32                    |          |         |           | 29        |           |                     |             |               | 60          |      |        |          |          |          |        |      |          |       |          |  |  |  |  |  |
| Move Y d1     | 26                      |         | 33       |          |         |         |        |         |          |              |             |                | 35                    | 33       |         |           |           |           |                     |             |               |             |      | 79     |          |          |          |        |      |          |       |          |  |  |  |  |  |
| Move Y d2     |                         |         |          | 50       |         |         |        |         |          |              |             |                | 31                    | 20       |         | 27        |           |           |                     |             |               |             |      |        |          |          |          |        |      |          |       |          |  |  |  |  |  |
| Move Z d1     | 29                      |         | 26       |          |         |         |        |         |          |              |             |                | 20                    | 25       | 21      |           |           | 20        |                     |             |               | 74          | 66   | 75     | 57       |          | 58       |        |      |          |       |          |  |  |  |  |  |
| Move Z d2     |                         | 40      |          | 27       |         |         |        |         |          |              |             |                |                       |          |         | 68        |           |           |                     |             |               | 60          |      |        |          |          | 36       |        |      |          |       |          |  |  |  |  |  |
| Rotate X d1   |                         |         |          |          |         | 34      | 20     |         |          |              |             |                | 16                    | 18       | 34      |           |           |           |                     |             |               |             |      | 81     | 23       |          |          |        |      | 63       | 40    |          |  |  |  |  |  |
| Rotate X d2   | 16                      |         |          |          | 19      | 19      | 17     |         |          |              |             |                | 18                    | 26       | 31      |           |           |           |                     |             |               | 76          |      |        | 84       | 23       | 45       |        |      | 62       | 41    |          |  |  |  |  |  |
| Rotate Y d1   |                         |         |          |          | 16      | 23      | 26     |         |          |              |             |                | 11                    | 32       | 37      |           |           |           |                     |             |               |             |      | 88     |          |          | 39       |        |      | 61       | 34    |          |  |  |  |  |  |
| Rotate Y d2   |                         |         |          |          | 11      | 38      | 20     |         |          |              |             |                | 15                    | 24       | 34      |           |           |           |                     |             |               |             |      | 75     |          |          | 39       |        |      | 61       | 38    |          |  |  |  |  |  |
| Rotate Z d1   | 17                      |         |          |          | 23      |         |        |         |          | 17           |             | 24             | 15                    | 19       | 43      |           |           |           |                     |             |               |             |      | 76     |          |          |          |        |      |          |       | 56       |  |  |  |  |  |
| Rotate Z d2   |                         |         |          |          |         | 33      |        |         |          | 20           | 20          |                | 16                    | 19       | 39      |           |           |           |                     |             |               |             |      | 76     |          |          |          |        |      |          |       |          |  |  |  |  |  |
| Blur d1       |                         |         |          |          |         |         |        |         |          | 63           |             |                | 16                    | 26       |         | 26        | 15        |           |                     |             |               |             |      |        |          |          |          |        |      |          |       |          |  |  |  |  |  |
| Blur d2       |                         |         |          |          |         |         |        |         |          |              | 63          |                |                       |          |         |           | 61        |           |                     |             |               |             |      |        |          |          |          |        |      |          |       |          |  |  |  |  |  |
| Opacity d1    |                         |         |          |          |         |         | 38     |         | 19       |              | 18          |                |                       |          | 25      |           | 29        |           |                     |             |               |             |      |        |          |          |          |        |      |          |       |          |  |  |  |  |  |
| Opacity d2    |                         |         |          |          |         |         |        | 17      |          | 20           |             | 29             |                       |          |         |           | 75        |           |                     |             |               |             |      |        |          |          |          |        |      |          |       |          |  |  |  |  |  |
| Brightness d1 |                         |         |          |          |         |         |        | 18      |          | 24           | 38          |                |                       | 19       |         | 40        |           | 20        |                     |             |               |             |      |        |          |          |          |        |      |          |       |          |  |  |  |  |  |
| Brightness d2 |                         |         |          |          |         |         |        |         |          |              | 17          | 42             |                       |          |         |           | 47        |           |                     |             |               |             |      |        |          |          |          |        |      |          |       |          |  |  |  |  |  |

■ Represent highest agreement % of each motion related to each meaning  
 ■ Represent highest agreement % of both meaning and motion

Total Participants = 100

The following table (table 4) demonstrates some insights from analyzing the pattern in the matrix (table 3). Characteristics of motion pattern can be divided into three groups by similarity: transposition in movement, transposition in rotation and transformation. Each motion group has its own strong area of meaning, emotional response and interaction function. For instance, transposition in movement supports an orienting function best because it also signifies the direction in interpretative meaning, whereas transposition in rotation supports working function better. Alerting function can apply to both rotation and transformation depending on the degree of intensity. Rotation motions are more tense and exciting than transformation motions, hence rotation could serve as a warning and high alert whereas transformation would serve better for cueing.

### Semantic Differential Analysis

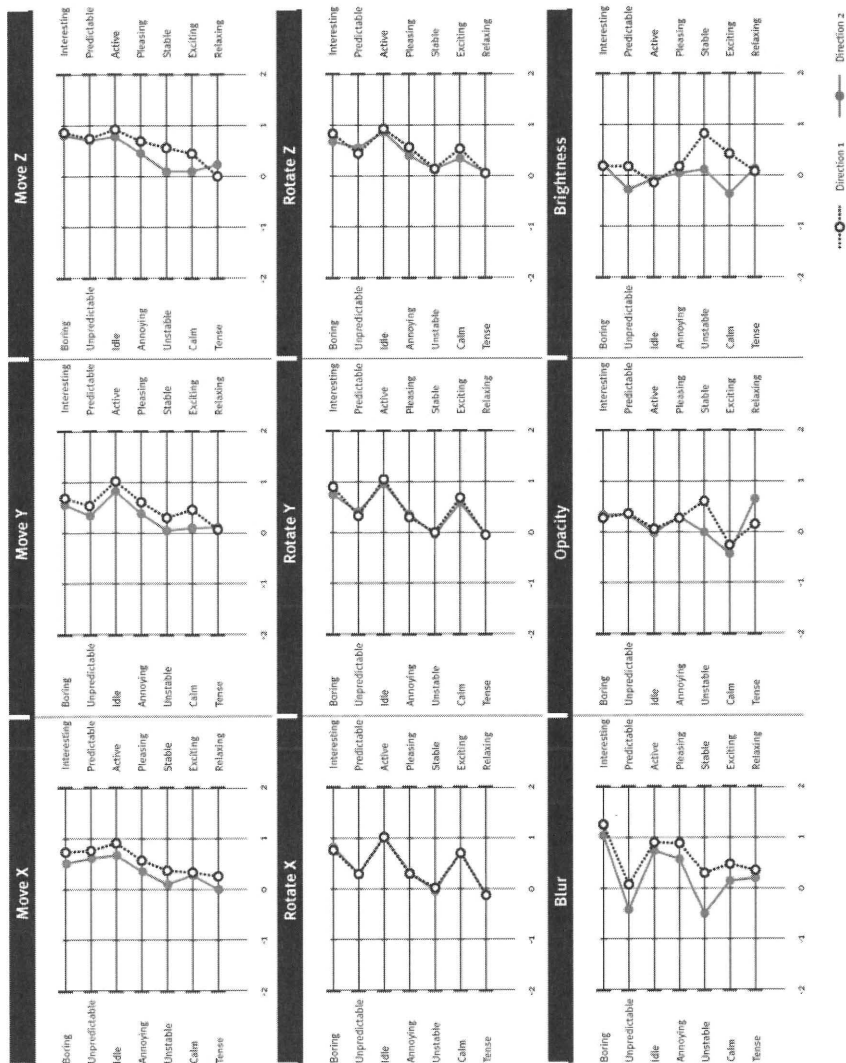
Because the answer for emotional response is in the format of semantic differential scales, semantic differential profile analysis is applied for detail analysis regarding how similar or different participants' responses to motion types are. To analyze emotional response relationships in detail, the means of the highest number of subjects using a particular scale were plotted into semantic differential profiles (see figure 9). Not only can this type of profile be used for comparing how participants respond to each motion type, but it also expresses how direction effects motion behaviors.

### Insight from Semantic Differential Analysis

Comparing these semantic differential profiles in all motion types and directions illustrate their similarity and difference pattern as described in the table 5. Two types of relationship between direction 1 and direction 2 and between motion types have been analyzed. Changing direction effects how participants respond to emotion in

|  | Insight from Analysis Interpretative Meaning [Q1]   | Insight from Analysis Emotional Response [Q2]   | Insight from Analysis Interaction Function [Q3]  |
|--|---|---|--|
| <b>Transposition:</b><br><b>Move X</b><br><b>Move Y</b><br><b>Move Z</b>       | In move X, Y, and Z, direction1 most have the opposite meaning with direction2. For instance, move X is more explicit in forward-reverse but for increase-decrease move Y is better. Move Z represents in advancing and retracting best.  | Most of move X, Y, Z motions are active and predictable.  | Move X, Y, Z in both directions are good for orienting and working.<br>Move Z d1 shares both transposition and transformation qualities. Beside orienting and working, move Z d1 also suggests alerting and prompting as transformation.       |
| <b>Transposition:</b><br><b>Rotate X</b><br><b>Rotate Y</b><br><b>Rotate Z</b> | Most participants did not recognize the direction of rotation. 3 choices: forward, reverse, and reveal have been selected extensively in rotate X and Y regardless of direction. Some rotation movies such as rotate X d2 has the highest selection rate in both forward and reverse.<br>Rotate Z has additional meaning beside forward-reverse in terms of focusing and emphasizing in both direction. | Rotation motions mostly elicit exciting and tense feeling.  | Most of rotation movements are good for working and alerting.<br>The best one for working is rotate Z d1. Rotate Y d1 has also high agreement in alerting!   |
| <b>Transformation:</b><br><b>Blur</b><br><b>Opacity</b><br><b>Brightness</b>   | In transformation, 3 meaning: reveal-conceal, focusing-losing focus, and emphasizing-de-emphasizing have been selected most. There is more strength in one than another such that brightness is better for emphasizing-de-emphasizing than opacity which is good for revealing-concealing. Blur has the highest agreement in all movies for focusing-losing focus.                                      | Most of transformation motions especially d2 are more idle, calm, and relaxed.<br>Blur in both direction is most interesting. | Interaction functions that transformation suggests most are verifying, prompting, and alerting.<br>Opacity has high agreement in prompting. For verifying, brightness and blur are high selected respectively. Blur is also good for alerting. |
| Note 1   |   | Active goes along with working  | Beside rotation motions, d2 of the rest of the motion types are high agreement in canceling function.  |

TABLE 4  
Example summary  
insights from analysis



**FIGURE 9**  
 Semantic Differential  
 Profile of Transposition:  
 Move X, Y and Z,  
 Rotate X, Y and Z and  
 Transformation in  
 direction 1 and  
 direction 2

| Insight from Analysis Emotional Response Pattern between d1 & d2 |  | Same | Similar | Different |
|--|--|------|---------|-----------|
| <b>Move X</b>  | Patterns are very similar in terms of quite interesting, predictable, pleasing, and active but d1 is more stable and relax than d2 |      | •       |           |
| <b>Move Y</b>  | Patterns are similar in the first 4 emotional categories. D1 is more stable and exciting than d2                                   |      | •       |           |
| <b>Move Z</b>  | Patterns are similar in the first 4 emotional categories. D1 is more stable and exciting than d2                                   |      | •       |           |
| <b>Rotate X</b>  | Patterns are the same  | •    |         |           |
| <b>Rotate Y</b>  | Patterns are the same  | •    |         |           |
| <b>Rotate Z</b>  | Patterns are similar except d1 has more pleasing and exciting than d2  |      | •       |           |
| <b>Blur</b>  | Patterns are similar except d2 has more unpredictable and more unstable than d1  |      | •       |           |
| <b>Opacity</b>   | Patterns are similar except d1 has more stable and d2 is more relaxing   |      | •       |           |
| <b>Brightness</b>  | Patterns are very different especially in d1 is more stable and exciting than d2   |      |         | •         |
| Note 1   | <i>Emotional categories that essentially effected by direction are unstable-stable, calm-exciting, and tense-relaxing.</i>         |      |         |           |

| Insight from Analysis Emotional Response Pattern between Motion Types |   | Same | Similar | Different |
|---|---|------|---------|-----------|
| <b>Brightness &amp; Opacity</b>                                       | Even though many participants said that they did not recognize the difference between those two motion types, the result of emotion response shows that brightness d1 is more stable and more exciting than opacity d1. Opacity d2 is more pleasing, calm, and relaxing than brightness d2. |      |         | •         |
| <b>Among Rotation</b>   | There is no difference in emotional response in cases of rotation regardless of axis and direction except rotate Z d1 which is more pleasing and exciting than d2   | •    |         | • Z       |

**TABLE 5**  
Example insights  
from emotional  
response analysis

transformation but there is little effect on rotation. This also is confirmed by verbal report from some participants; they did not recognize the difference between rotation in direction 1 and rotation in direction 2.

Going beyond descriptions of the data, data was analyzed to examine whether participants' demographic factors, for example culture, professional training (e.g., designer/non-designer), gender and age range, influence the way they answer questions. All data was recoded into SPSS analysis program. The results are summarized in four categories: Western-Eastern, Designer-Non-designer, Male-Female and five ranges of age.

The analysis of results in question 1: interpretative meanings and question 3: interaction function are different, based on demographic factors as follows:

**IN CULTURE:** western-eastern, the analysis of results demonstrates that participants in eastern culture interpret and understand motion differently

**INFERENCEAL  
STATISTICAL  
DATA ANALYSIS**

from western culture. Looking closely in each motion type, there is high agreement regardless of culture in transformation motions but for transposition western and eastern participants tend to respond differently.

IN PROFESSIONAL TRAINING: designers-non-designers, the analysis of results demonstrates that designers interpret and understand motion differently than non-designers, especially in move Z. Again there is no differentiation of responses in transformation motions between those two groups.

IN GENDER AND AGE: the analysis shows much higher agreement than those of culture and professional training. There is almost no differentiation of response between male and female in interpreting and understanding motion.

The analysis in the emotional response categories has much higher agreement than the answers in interpretative meaning and interaction function, especially in the first 4 categories: Boring-Interesting, Unpredictable-Predictable, Idle-Active and Annoying-Pleasing. There is almost no significant difference in how western and eastern participants feel about motion.

## APPLYING FINDINGS

Insights from the analysis provide beneficial guidelines for both designers who would like to use motion more effectively and researchers who are interested in building motion language.

For designers, a Motion Library will be generated by integrating the results and analysis from all three answers: interaction function, interpretative meanings as sub-functions and emotional responses. The Motion Library serves as a resource for linking fundamental knowledge of motion, created by experiment, to how designers can apply that knowledge in practice. Not only does the Motion Library comprise the meaning of each motion type represented, it also includes the patterns and relationships among them. This library helps designers to narrow down and select appropriate motions to apply to an interaction function, based on understanding how users respond to each type of motion. The Motion Library also applies FEM

(Function-Emotion-Motion) framework (figure 10 below). FEM framework is the logic behind the process of how to use the Motion Library. One interaction function can be represented by several alternative motions. To select an appropriate motion, designers need to consider what interaction function and type of emotional response they need. Then match one or more emotional responses that are associated with the particular interaction function to obtain possible motions (see figure 10). The motion possibilities are selected from the motion library, determined from experimental results. In practical application of this work, the ensemble of interaction functions needed and their contrasting behaviors and possible motion representations enter into the selection and planning of interactive signals.

For researchers, the methodology of how to set up an experiment to explore more motion variables has been explained throughout the methodology section. Researchers can use Mix and Match Motion Variables Framework (table 1) as the foundation to set up the scope of their experiment. Sharing results and analysis in future experiments can expand the motion library and fill out the motion language.

## DISCUSSION AND FURTHER DEVELOPMENTS

The three main contributions of this research are: the establishment of a motion structure as a systematic foundation for exploring motion meanings and their affordances, the methodology of developing a motion experiment and examples of how knowledge from this type of research can be applied to design practice.

The motion structure is generated from analyzing and synthesizing reviews of literature related to motion. It provides a systematic approach for integrating

**FIGURE 10**  
FEM (Function-Emotion-Motion) Framework and sample application

| FEM framework:<br>Matching Interaction Functions and emotional responses to Motions |   | Interaction Functions (F)  | Emotional Response (E) | Motion Possibilities (M)  |               |             |
|---|---|--|------------------------|---------------------------|---------------|-------------|
| F <sub>1</sub>  | $\left[ \begin{array}{c} E_1 \\ E_2 \\ \vdots \\ E_n \end{array} \right]$ | $\left[ \begin{array}{c} M_1 \\ M_2 \\ M_3 \\ \vdots \\ M_n \end{array} \right]$ | Advancing              | Active Predictable        | Move X d1     | Move Z d1   |
|   |   |  | Retracting             | Predictable               | Move Y d2     |             |
|   |   |  | Increasing             | Active                    | Move Y d1     | Move Z d1   |
|   |   |  | Decreasing             | Predictable               | Move Y d2     |             |
|   |   |  | Forwarding             | Active Exciting           | Rotate Z d1   |             |
|   |   |  | Reversing              | Predictable               | Move X d2     |             |
| Alerting  |   |  | Revealing              | Active Tense              | Rotate X d1   | Rotate Y d1 |
|   |   |  | Focusing               | Interesting Pleasing      | Blur d1       | Rotate Y d2 |
|   |   |  | Emphasizing            | Calm Stable               | Brightness d1 | Opacity d1  |
| Canceling   |   |  | Concealing             | Calm Relax                | Opacity d2    |             |
|   |   |  | Losing focus           | Interesting Unpredictable | Blur d2       |             |
|   |   |  | De-emphasize           | Idle Relax                | Brightness d2 | Opacity d2  |

E<sub>1</sub>, E<sub>2</sub>, ..., E<sub>n</sub> are a set of emotional responses that F<sub>1</sub> (an Interaction Function + a Sub function) should consider. M<sub>1</sub>, M<sub>2</sub>, ..., M<sub>n</sub> are motions corresponding to the same set of interaction function and emotional responses. Matching possible motions requires insights from matrix pattern (e.g. table x.x).

all motion variables. This motion structure is a foundation for the Mix and Match Motion Variable framework (*table 1*). After setting the scope for motion variable investigation from the motion framework, the experimental research begins.

One of the most critical processes in developing the experiment is developing choices for interpretative meaning in question 1 and interaction function in question 3. All choices in question 1 should have the same level of interpretation. In this experiment, the descriptive level was not applied. Interaction function choices depend on the nature of the selected set of motion variables. For instance, if researchers are interested in the relationship of motion between 2 objects in the same space, comparing function could be one of the choices. For future experiments, choices might require modification in order to be suitable for a particular motion variable set. The pilot study is an essential step to verify whether the choices provided cover all possibilities of interpretative meaning and interaction function.

From high-low agreement in matrix analysis and significant difference testing, the result demonstrates that emotional responses tend to be universal. On the other hand, culture and professional training affect the way individuals interpret motion, especially in transposition motion. Focusing on only the emotional dimension could allow us to acquire a global meaning of motion in terms of emotional response. For interpretative meanings and functions, constraining the demographic group, especially by culture and professional training, would lead to results more specifically useful for particular groups.

This research is a starting point for motion for interactive media. The research intention is to establish a research system that can be built on. Completing the Motion Library requires a great number of experiments. The possibilities are immense as shown in table 1. Analysis of results of motion variable relationships among cooperative experiments can contribute deeper understanding of motion language. This research identified reasonable methodology to obtain the motion pattern and demonstrate that meaning and qualitative attributes are not beyond serious study. The development and results can feedback to practice. This knowledge can assist designers in understanding a language of motion leading to its more effective use.

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### Author Notes

**CHUJIT JEAMSINKUL** is a Ph.D. candidate at the Institute of Design, Illinois Institute of Technology, where she is supported by a Royal Thai Government scholarship. With experience in both design practice and teaching, her research focus is on communication problems in new media with a view to user-centered solutions.

**SHARON HELMER POGGENPOHL** teaches in the graduate program at the Institute of Design, Illinois Institute of Technology, where she also coordinates the Ph.D. in Design program. As editor and publisher of *Visible Language*, she has a practical interest in design research and its publication.

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