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Susanne Delzell
San Jose State University

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Delzell, Susanne Ruth, M.A.

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U·M·I
300 N. Zeeb Rd.
Ann Arbor, MI 48106

THE EFFECTS OF CONTEXT ON READING MISORIENTED WORDS

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Master of Arts

by

Susanne Delzell

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APPROVED FOR THE DEPARTMENT OF PSYCHOLOGY

Kevin Jordan, PhD

Robert Cooper, PhD

Walter Johnson, PhD

APPROVED FOR THE UNIVERSITY

ABSTRACT

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by Susanne Delzell

The present study examines the impact of repetition and level of contextual priming on reading misoriented words. Upright words were either presented unprimed or preceded by one of two levels of contextual priming in training. When the words were subsequently repeated in various orientations, the contextual priming produced no facilitation of response time relative to unprimed words. The unprimed words, however, were identified faster than both primed words and words that were not seen in training. The reduction in the effects of misorientation was attributed to the perceptual processing involved in reading the unprimed words. The results will be discussed in terms of their compatibility with Mental Rotation and other models used to explain orientation effects.

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Susanne Delzell

San Jose State University

Effects of Context

Requests for reprints should be sent to Susanne Delzell, Department of Psychology, San Jose State University, San Jose, California 95192

Abstract

The present study examines the impact of repetition and level of contextual priming on reading misoriented words. Upright words were either presented unprimed or preceded by one of two levels of contextual priming in training. When the words were subsequently repeated in various orientations, the contextual priming produced no facilitation of response time relative to unprimed words. The unprimed words, however, were identified faster than both primed words and words that were not seen in training. The reduction in the effects of misorientation was attributed to the perceptual processing involved in reading the unprimed words. The results will be discussed in terms of their compatibility with Mental Rotation and other models used to explain orientation effects.

The Effects of Context on Reading Misoriented Words

In 1971, Shepard and Metzler asked subjects to judge whether or not two identical but differently-oriented shapes were normal or mirror images of each other. They reported a linear increasing function of response times with increasing angular departure between the two shapes. The steady increase in response times was taken as an indication that subjects were imagining one shape rotating into congruence with the other in order to make a comparison. A serial, analog, discrete stage, processing model dubbed Mental Rotation was subsequently proposed to account for the phenomenon. According to the model, the image passes over a "trajectory of intermediate locations" (Cooper & Podgorny, 1976) between its point of origin and point of destination. As the distance between these points lengthens, the time it takes to complete the rotation is expected to increase (Cooper & Podgorny, 1976). In processing terms, the internal operation is considered to be an analog of an external rotation of a corresponding stimulus (Cooper & Shepard, 1973). In other words, the mental operation performed upon the proximal stimulus representation is functionally like the spatial operation that would be performed on the distal stimulus if two physical objects were being aligned along identical axes.

The Mental Rotation (MR) model is compelling in cases where the orientation function is increasing and indisputably linear because it accounts systematically for the response times to make decisions about many different types of misoriented stimuli such as alphanumerics, objects, and words. Given an object in a particular orientation, the steady response time to rotational distance ratio allows for predictions to be made about the size of the processing cost likely to be encountered in recognizing the object. Another positive aspect of the model is the appealing rationale it provides for the processing phenomenon.

Mental rotation seems a likely strategy because it mirrors the solution to the problem of misorientation in the physical world. In other words, it simplifies the comparison task by adjusting the spatial alignment of stimuli to be equivalent. The alignment process factors out the divergent orientation information and the comparison proceeds on the stimulus features alone. With ambiguous orientation information effectively removed by mental rotation, an internal representation of the stimulus need not be stored in more than one orientation.

Mental rotation has certain implications for information processing within the sphere of its influence. Processing described by the model is serial in the sense that stages of processing are locked into a sequence of operations with later stages depending on the output of prior stages. These stages are discrete in regard to processing. There is no account of overlapping of processing or representation built into the model. The rotation phase is positioned between early perceptual processing of visual elements and later, higher-order processing resulting in recognition. Since stimulus resolution is held to be dependent on rotation, any higher-order processing that depends on resolution of orientational disparity would be expected to follow rotation.

Shepard's MR model accounts for the observed linear increasing function between response latencies and stimulus angular departure in terms of three basic assumptions. First, the mental image represents the stimulus internally and carries all the information encoded from the distal stimulus over the rotational path in an analog (holistic) manner. Second, there is a second-order (i.e., functionally) isomorphic correspondence between the image and the visual stimulus. In other words, the operations that can be performed on the stimulus have analogous operations for the image (Shepard & Cooper, 1982).

Third, the imagined rotation serves to bring the image and the distal stimulus into congruence and thereby allows recognition to occur (Shepard & Cooper, 1982). As indicated by the assumptions above, this model has the ability to account for the linear increasing function with a simple time/distance formula (i.e., the greater the angular departure between stimuli, the greater the time needed to resolve the difference in orientation). In regard to the function, it is important to note that evidence for mental rotation is solely dependent on a linear increasing function. Although it may be argued that other processing factors intervene to alter the function somewhat, the more the function departs from linearity, the less compelling the evidence for a mental rotation interpretation. Departures from linearity are a major concern in evaluating the appropriateness of the MR model for different instances of decisions made regarding misoriented stimuli. They will be discussed below.

Other models of visual pattern recognition have been proposed to explain how recognition of misoriented stimuli occurs. Most of these models do not attempt to account for the time used to resolve a misoriented stimulus. Instead, they assume that orientation-invariant attributes (e.g., overall shape, angles, major axes, and contour) are responsible for recognition. Some examples of these models are: Beiderman's Geon model (Beiderman, 1987), McClelland and Rumelhart's Interactive Activation model of misoriented word recognition (McClelland & Rumelhart, 1981), and Marr's 2 1/2 D Sketch model (Marr & Nishihara, 1978). Although these models offer solutions to the problem of misorientation, they have not had the amount of attention focused on them that the MR model has. This may be due to the fact that the predicted stable increase in reaction times to a stimulus discrimination task make the serial analog model especially amenable to testing. Other models that would explain the phenomenon of orientation effects do not offer such a clear cut objective measure. In a large number of studies over the years, the mental rotation function has proved to be highly robust and MR has found wide acceptance.

Scope of the Mental Rotation Model

The MR model serves to accommodate data derived from various task/stimulus combinations that have been used in visual comparison task research programs (see Corballis & Cullen, 1986). The range of stimuli tested has included shapes, alphanumerics, words, and line drawings of natural objects. Stimuli have been coupled with a range of tasks including mirror-image discrimination, identification, matching, lexical decision, and categorization (Corballis & Cullen, 1986; Corballis & Nagourney, 1978; Jolicoeur & Landau, 1984; Koriat & Norman, 1985a; White, 1980). In addition, experiments have differed with regard to the type of comparison to be made between stimuli. Some have required comparison of two external stimuli and others have required comparison between an external stimulus and a memory representation (S. Shepard & D. Metzler, 1988). Overall, orientation effects have proved to be robust. However, in certain cases, the effects of misorientation have been slight or even absent. Typically, comparison tasks involving novel stimuli and mirror-image reversals have shown response latencies to be dependent on orientation, whereas well-practiced or highly-familiar stimuli (e.g., alphanumerics) paired with tasks other than mirror-image discrimination have not (see Bethell-Fox & R. Shepard 1988; Jolicoeur & Landau, 1984).

In cases where orientation effects are obtained, the variation in response time function slopes can usually be described as monotonically increasing but not strictly linear.

Task/stimulus changes and practice have been found to produce variation in function slope (Corballis & Cullen, 1986; Jordan & Huntsman, 1990). These have been recorded across a range of mental rotation experiments (S. Shepard & D. Metzler, 1988). These variations require explanation in light of claims that the rate of mental rotation does not change with practice (Cooper & Podgorney, 1976). If rotation rates were assumed to be variable, variations in function slope that have been observed with task/stimulus changes would be consistent with changes in mental rotation speeds ranging from 20 degrees per second (dps) to 600 dps. The meaning of the differences in recorded response times is unclear. They could be interpreted as changes in the global rate of mental rotation or as an overall change in the magnitude of orientation effects.

One process that has been proposed to account for rotation response times that are slower than normal is known as piecemeal rotation. According to this theory, some stimuli are too complex to be fully integrated into an holistic image that must be maintained intact across an imagined spatial rotation. In such a case, observers are expected to break a stimulus down into parts which are subsequently rotated in a sequential, "piecemeal" fashion (Bethell-Fox & Shepard, 1988; Robertson & Palmer, 1983; Shepard & Cooper, 1982). This explanation can reconcile anomalous data with the MR model when the function is monotonically increasing but response times exceed the normal 400 to 600 dps range. There has been criticism against using the complexity argument to account for out-of-range rotation rates. Yuille and Steiger (1982) have provided data to show that rotating a subset of features of a complex stimulus is often sufficient to accomplish a discrimination task and that complexity has no effect on response times unless its evaluation is critical to the task being performed. They claim that complexity effects failed to show up in previous studies because the fact that subjects can make use of featural redundancy was not taken into account. Their research undermines support for holism in processing mental images.

Another explanation is often proposed when response times are faster than expected. Increasingly shorter response times are frequently recorded when an observer is either very familiar with the stimuli being used, as in the case with alphanumerics, or has received extensive practice with the stimuli (Corballis & Nagourney, 1978; White, 1980). In the case of familiarity, recognition may occur equally fast in any orientation. Practice frequently causes the slope to decrease gradually with repeated exposures to the same stimuli. Both familiarity and practice are thought to decrease response times by forming memory representations of stimuli in multiple orientations (Jolicoeur, 1985; Tarr & Pinker, 1989). Repeated exposure to the same stimuli in a visual comparison task often results in facilitation that is unequal across orientations (Jolicoeur & Milliken, 1989). If rotation is holistic as Shepard's model states, it is difficult to account for such extreme fluctuations in response times unless they can be explained by some auxiliary process.

Tarr and Pinker (1989) have attributed the facilitation to memory storage of stimuli in multiple orientations to frequent environmental or experimental encounters with them. They argue that when the stimulus is presented in a previously stored orientation, recognition is not expected to require rotation. When presented in an unstored orientation, the mental representation of the stimulus is expected to be rotated to the closest stored position rather than to the canonical position. A similar process involving a short-term memory trace has been dubbed backward alignment (Koriat & Norman, 1988). In this case, the image of the present stimulus is assumed to be rotated into alignment with the perceptual trace of previous presentations of an identical stimulus. Both processes decrease response time by decreasing the required rotational distance.

A third phenomenon related to practice has been more difficult to integrate into the MR model because it causes the slope to become non-linear. With increasing practice, a quadratic trend in the function relating reaction time to stimulus orientation often develops (Koriat & Norman, 1985b). Generally, this appears as a flattening of the curve (or faster response times) at orientations close to upright or 0 deg (Cooper & Shepard, 1982). In a manner similar to stimulus familiarity, response time facilitation with practice has been explained by frequency of environmental encounters with a stimulus in a near-upright position. For example, due to slight head tilt or placement of objects on uneven surfaces, we may often get a retinal projection of an object that is slightly misaligned with vertical even though the object is for all practical purposes upright. To avoid errors in classification of these encounters, we may develop an expanded range for the category "vertical". This phenomenon has been referred to as broad storage, or broad tuning, of the pattern (Hock & Tromley, 1978; Koriat & Norman, 1985b).

Though large amounts of practice may also cause the slope to flatten completely, practice is not always effective in reducing response times. One such case, where slope has been found to remain stable despite practice, is discrimination of mirror-image reversals (Shepard & Cooper, 1982). This is assumed to occur because a handedness discrimination is required for determining whether or not a match is present. The implied reference to body coordinates would seem to require that the canonical reference frame of the stimulus be brought into alignment with the direction an observer is facing.

Mirror-image identifications are thought to require congruency between stimuli under comparison, and therefore, a complete rotation between stimuli.

In an effort to align different characteristics of orientation effects with the MR model, researchers have been presented with still more challenging research data. Koriat and Norman (1985a) presented evidence to show that a flattening of the function at slight degrees of misorientation emerges when the stimuli have been encountered an equal number of times in several orientations, or when they have been repeatedly presented at 0 deg of rotation. In their experiment, subjects were trained with and subsequently asked to identify upright and mirror versions of novel, letter-like characters. When subjects were asked to identify normal upright characters, the resulting reaction times exhibited a non-linear (quadratic) trend, while the mirror reversals showed the classic linear trend. However, after further practice identifying rotated characters presented equally often in different orientations, the quadratic trend for the upright characters became more pronounced and the results for the mirror reversals became quadratic as well. Because test stimuli were never shown at non-upright orientations, Koriat and Norman at first rejected the idea that the non-linearity was due to stimulus storage in multiple reference frames but subsequently attributed the results to the backward alignment process described earlier (i.e., the process of rotation to the coordinates of the previously-stored stimulus). Backward alignment is assumed to reduce response times by reducing the rotational distance to congruence. This solution to non-linearity becomes a sort of MR modification in effect. By invoking the idea of stimulus storage in multiple reference frames, it accounts for the unequal variation in response times across orientations.

Another candidate hypothesis for explanation of observed variations in the classic linear mental rotation function is known as instance-based skill acquisition (Masson, 1986). In contrast to the explanations mentioned above, Masson's proposal makes no claims of mental rotation being necessary for overcoming the effects of misorientation in his study. Using words as stimuli in a word identification task, Masson found that orientation effects were dependent on transfer of specific visual elements within words. This research supports the idea that orientation effects are due to local inconsistencies between misoriented stimuli and their internal representations. Masson argues that as observers become more practiced or familiar with local elements of the stimuli, less information remains to be resolved and consequently less time is required for visual comparison or identification. Thus, the response time reductions are not due to some general transformation process but to memory for features that are specific and unique to the stimulus involved. This indicates another type of process (i.e., resolution of feature inconsistency) as a driving factor for orientation effects. In a similar vein, Koriat and Norman (1989) have argued that misorientation may cause an increase in response time by disrupting the element-position mapping within words. They hypothesize that more disruption results in an increase in time to resolve the stimuli.

In an attempt to reconcile the body of research on orientation effects with the MR model, Tarr and Pinker (1989) have presented a comprehensive and impressive review of the data collected to date on misoriented visual comparison tasks. They conclude that a combination of mental rotation and multiple-frame storage models can account for variability in the results. In agreement with Koriat and Norman's backward alignment hypothesis, they argue that subjects rotate an image of a stimulus to its closest previously-stored position in order to make decisions regarding it. It follows that observed variations in rotation "rates" are due to differences in the angular rotational distances between the canonical and previously-stored stimulus orientations.

The success with which experimental results have been rendered compatible with the MR model is impressive. However, in view of the variations in results and in spite of Tarr and Pinker's hybrid solution to the problem, the body of research collected to date invites construction of a more parsimonious model than MR. Whereas mental rotation in its original form eliminated the need for multiple storage of stimuli in different orientations, explanations used to align anomalous data with the model (e.g., backward alignment or multiple representations) fall back on multiple storage assumptions. Because of their ability to represent a large variety of stimulus properties simultaneously, models that emphasize connectionist networks and parallel processing may serve better to accommodate the variations than serial models. It is also possible that some of the processing that results in orientation effects is not dependent on the orientation of the stimulus. Alternatively, it could be the case that mental rotation is a sub-routine of a more general process that resolves misoriented stimuli.

Higher-Order Influences

The question of what is being processed under conditions of misorientation is a fundamental one. The body of research that has been accumulated is limited in a notable way. It focuses exclusively on physical attributes of stimuli. Since these visually encoded properties are the components of the image, they are responsible for resolving misorientation properties according to MR. Mental Rotation is a data-driven model in which the visual transformations necessarily precede higher-order or conceptual processing. Other models that focus on top-down processing for resolution of misoriented stimuli do exist. McClelland and Rumelhart's Interactive Activation (I.A.) Model of word recognition is a prime example of a scheme that relies heavily on lexical associations or context for perception of words presented in any orientation (McClelland & Rumelhart, 1981). This model rests on the assumption that basic low-level sensory information enters into the visual system and immediately makes contact with high-level conceptual information. From this point, bottom-up and top-down processing go on in parallel with mutual interactions. Higher-order stimulus attributes are partially responsible for driving orientation effects and they may be functional in making stimulus decisions with incomplete stimulus resolution in an interactive model.

Words, with their semantic properties, lend themselves to manipulations of contextual information. Mental rotation studies have been performed that vary lexicality or semantic content of words (e.g., word/non-word discriminations). However, in this area of research semantic differences are confounded with physical differences in the stimuli or in the amount of stimulus information that must be processed. For instance, a non-word can contain irregular or low-frequency letter combinations that, when observed, eliminate the need for further processing in order to determine lexical status. The experiment described here was designed to disentangle semantic and perceptual factors that contribute to orientation effects.

Words have been used as stimuli by a number of researchers in mental rotation experiments and have shown strong orientation effects (Jordan & Huntsman, 1990; Koriat & Norman, 1985a). They are interesting stimuli because they are separable into meaningful parts at several different levels (e.g., features, letters, and letter combinations).

In addition, they lend themselves to manipulation of processing levels. Jacoby (1983) has demonstrated the effects of availability of types of data input (i.e., visual and contextual) on memory for words. He used antonym pairs (e.g., HOT/COLD) in 3 conditions in the training phase of his experiment. One member of the antonym pair served as a cue word and the other as a target word. In the first condition, NO CONTEXT, a row of xxxx's was substituted for the cue word. These appeared on the computer screen for 1 s followed by a 1 s blank screen. The target word appeared immediately after the blank screen and stayed on for 1 s. In the second condition, CONTEXT, the cue word (e.g., HOT) was presented followed by a blank and a target word (e.g., COLD) in the same manner as condition 1. In the third condition, subjects saw the cue word followed by a blank and a row of question marks. All stimuli were presented in their upright, canonical positions. For the first two conditions, the task was to read the target word as rapidly as possible and for the last condition subjects were to generate the target word (the antonym of the cue word) verbally as rapidly as possible. The conditions presented subjects with different levels of two types of input data for encoding; visual and contextual input. These data input types were demonstrated to generate what has been referred to as different levels of processing (Craik & Lockhart, 1972; Craik & Tulving, 1975). According to Craik and Lockhart's theory, the depth of the processing level is contingent on the amount of association or contextual input surrounding the stimulus. Data that is primarily visual in content is assumed to be processed at early encoding stages and at a shallow level. Contextual data, on the other hand, involve associations between the target stimulus and other stored representations of stimuli, and are believed to be processed at later stages, after perceptually-based encoding is complete. In condition 1, subjects saw no cue word and thus had no contextual information in advance but did have access to the visual information in the target word. In condition 2, subjects had both kinds of information and in condition 3, they had contextual information but no visual information. Jacoby found that the level at which a word was processed influenced its retrieval in memory tasks and that recognition memory was affected differently than recall memory. Recognition memory was facilitated by visual or perceptual information but not by contextual information and the reverse was true for the recall task. These findings and the many response time function variations that have been induced with task/stimulus changes suggest a test to determine if relative levels of memory activation or types of priming can have an impact on orientation effects. Given that inconsistencies abound in research on orientation effects, it seems likely that a more complex relationship exists between memory storage and misoriented stimuli than a multiple-storage hypothesis could accommodate.

In order to explore the relationship between types of priming and size of orientation effects, an experiment was conducted using short familiar words as stimuli and identification as the task. The paradigm for the training phase of the experiment was borrowed from the experiment of Jacoby's discussed above. The research question of general interest was whether or not pre-exposure to word information could reduce orientation effects upon a second encounter with the same word. In addition, the type of information accessed from the pre-exposure was of interest. Jacoby's paradigm allows for the consideration of two hypotheses about the type of information that might be effective. First, the higher-order, semantic associations between words (antonyms in this case) may cause a word to be processed at a deep level and consequently activated more easily when reencountered in a different orientation. Alternatively, under the same circumstances, lower-order perceptual detail may be the source of orientation effect reduction. If the first hypothesis proves to be correct, contextual input of the sort engendered by the context and generate context conditions in Jacoby's experiment should produce faster word identification times than a control condition composed of similar words but without the benefit of pre-exposure. Support for the second hypothesis would be demonstrated by a decrease in orientation effects with visual pre-exposure to the word in absence of a contextual cue.

Method

Subjects

Subjects were recruited and paid for their participation by a subject procurement agency at NASA-Ames Research Center, where the experiment was conducted. Seventeen males and seven females participated in the experiment for a total of 24 subjects. Subjects were between the ages of 18 and 40 with normal or corrected-to-normal vision and all were native English speakers.

Stimuli and Apparatus

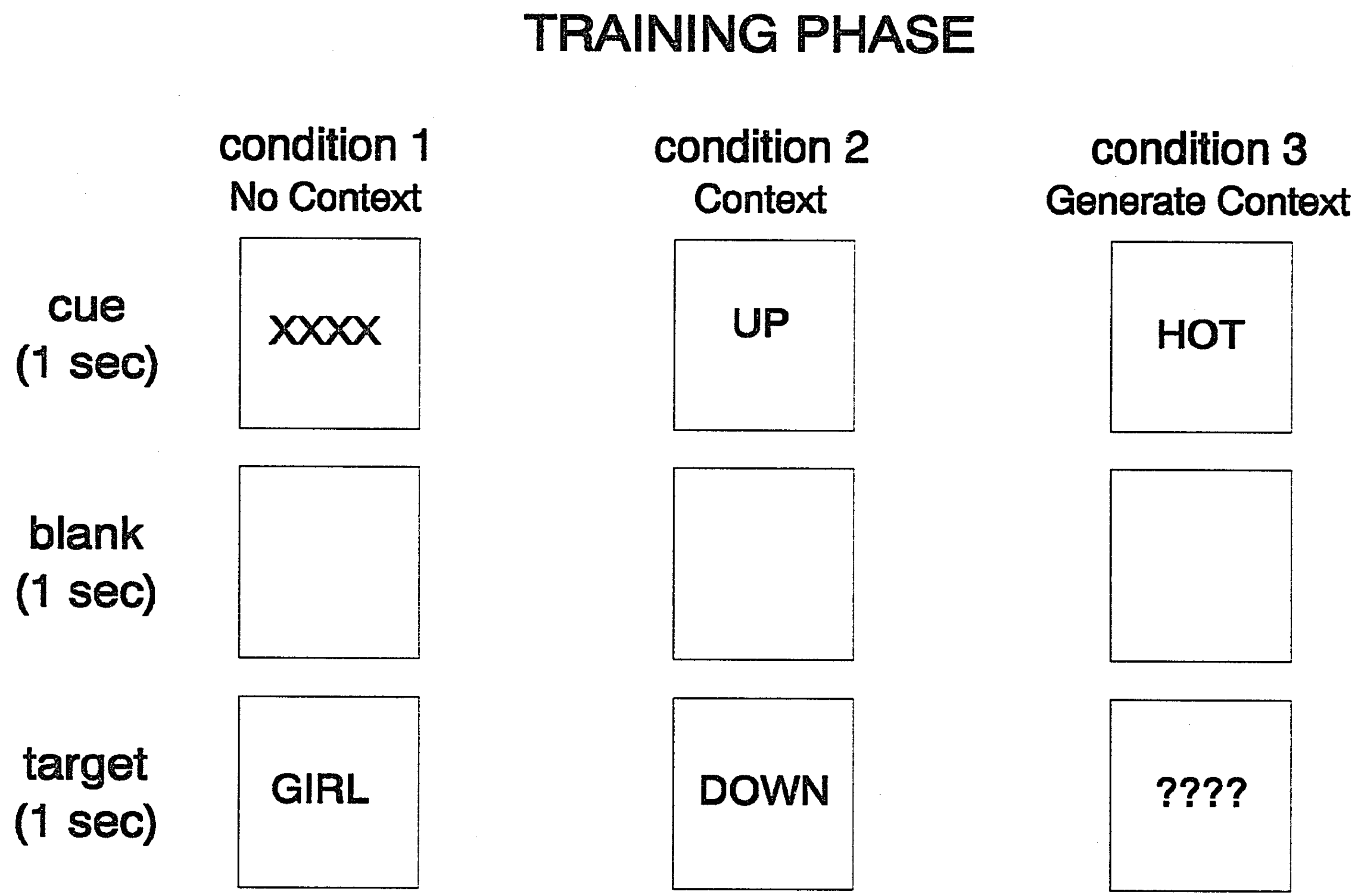
The experiment was conducted in a small experimental booth. An IBM compatible 386 computer with an NEC Multisync 3D monitor was used to display the stimuli and a voice key connected to a microphone triggered the onset of response timing. The Micro Experimental Lab (MEL) software package managed the screen display and data recording for each subject. The stimuli were four and five-letter familiar words that were members of pairs of antonyms (e.g., HOT/COLD) and substitutes for antonyms (a row of ????'s or a row of XXXX's). One member of each pair was designated as a cue word and the other member was designated as the target. Subjects were instructed to attend to cue words but to verbally respond to target words only. To avoid confusion regarding the response, all cue words were displayed in white and all targets were blue. Words and substitutions were always presented in uppercase letters and centered in the middle of the screen.

Design

A 4 (context levels) by 7 (orientations) within subjects design was used and the dependent measure was response time. There were two phases to the experiment, a training phase and a test phase. In each, the basic task was to identify a target word as rapidly and as accurately as possible after its appearance on the screen. The conditions were counterbalanced for order in both phases of the experiment. The sequence in the practice trial consisted of a cue, a blank screen, and the target. Each appeared on the screen for 1 s with no breaks in between.

Training phase. There were three conditions in the training phase of the experiment. An example of the sequences for each condition in training is presented in Figure 1. Subjects responded to 28 trials in each of three conditions, for a total of 84 trials in the training phase. All words displayed in the training phase were at upright positions. Five practice trials were administered before starting the block of trials for each condition. The purpose of the manipulation was to induce different levels of processing in the target words which were subsequently presented in the test phase of the experiment. The training conditions represented three levels of context information. In the NO CONTEXT condition, subjects were presented with a row of XXXX's in the place of the cue antonym which was followed by the appearance of the target word. The absence of the context cue

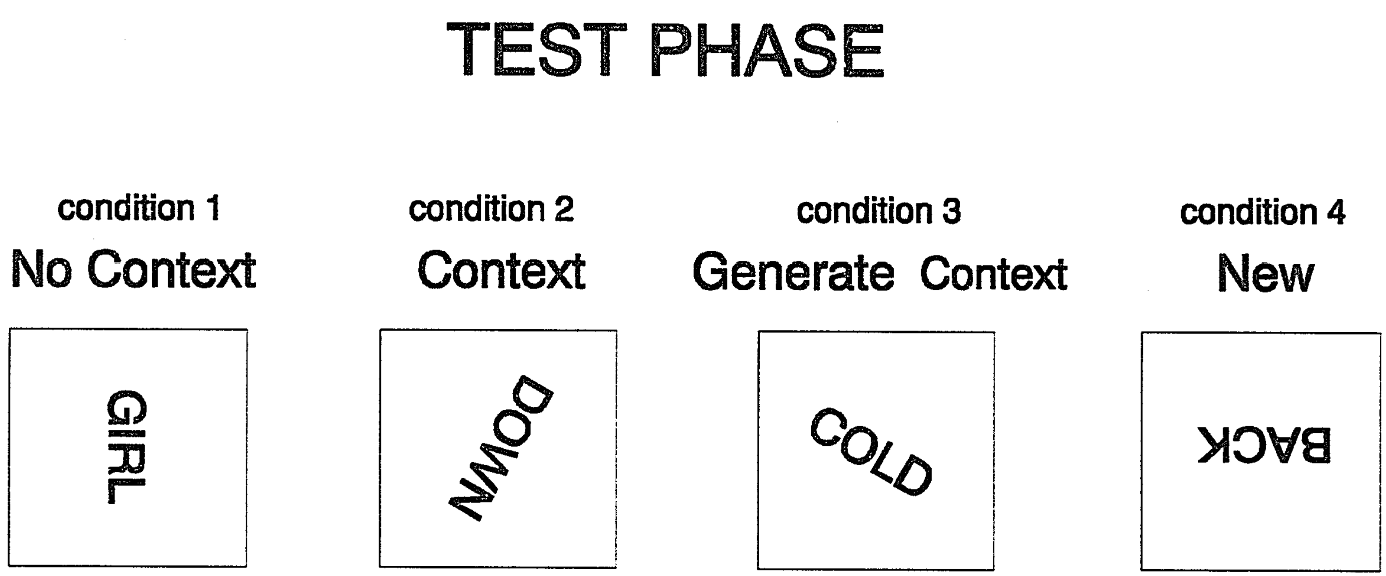
Figure 1. Presentation sequence seen in training.



in this condition forced subjects to rely on the perceptual content of the target for their response. In the CONTEXT condition, subjects saw both the cue and the target antonym. Consequently, they were able to guess what the target word would be before it appeared on the screen even though they were instructed not to respond until it was present. Contextual and perceptual information were available to subjects in this case. In the GENERATE CONTEXT condition, a row of ????'s was substituted for the target. They served as a prompt for subjects to respond verbally with the appropriate target antonym based upon the information from the cue antonym. Here, the contextual information needed to formulate a response was present and perceptual information was absent. Because the response had to be generated from context, target words in this case were expected to be processed at a deep level.

Test phase. There were four conditions in the test phase of the experiment which yielded a total of 112 trials (see Figure 2). The trials consisted of all the target words presented in training plus a new group of 28 words that served as a control. The word control condition was composed of antonym members of the same type presented in the other three conditions. Only the target members of the antonym pairs were seen in the control condition since they were not present in training. A list of all the target words with their respective cues is presented in Appendix B. Target words from each of the three conditions in training were presented in seven orientations (four words were presented in each of seven orientations). The orientations ranged from 0 deg to 180 deg in 30 deg increments . Figure 3 provides examples of target words in these orientations.

Figure 2. Targets from training phase plus new words.



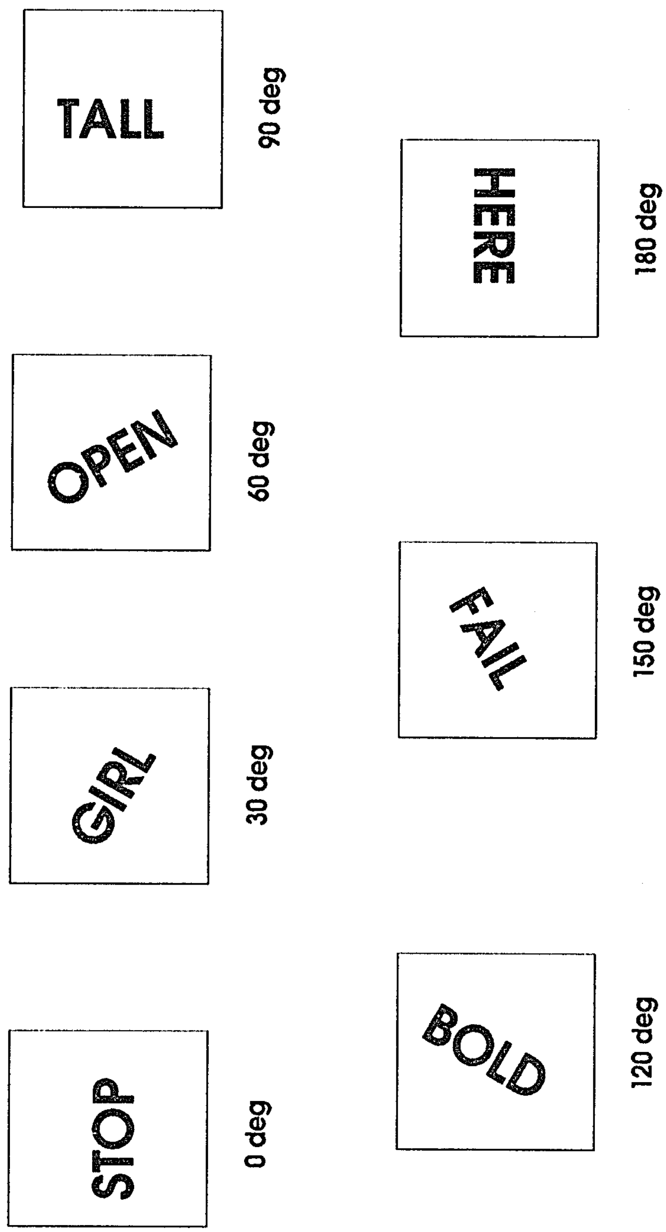


Figure 3. Illustration of sample target words at all test orientations.

Procedure

In both phases of the experiment, the basic task was to identify a target word as rapidly and as accurately as possible after its appearance on the screen. Individual trials and practice trials for each condition were self-paced and initiated by the subject with a press of the spacebar on the keyboard. Responses were timed and recorded from the onset of the target word (or a substitution for the target word) to the onset of the vocal response. The purpose of the manipulation was to induce different levels of processing in the target words which were subsequently presented in the test phase of the experiment.

Results

Identification times from the test phase of the experiment were analyzed in a 4 (conditions of processing) x 7 (orientations) within subjects analysis of variance. The original plan called for analysis of the response times for the training data. This plan was abandoned because noise from construction work in the building triggered the voice key early and because some subjects were slow to learn the task in training. Figure 4 shows response time as a function of orientation for the test phase. The NO CONTEXT condition yielded the most rapid response times in all but two cases of all the orientations within conditions tested. In Figure 5, the CONTEXT and GENERATE CONTEXT conditions have been combined to show the effects of the NO CONTEXT condition more clearly. The main effect of orientation was statistically significant [$F(6,138) = 38.98$, $p < .001$]. The main effect of condition was also significant [$F(3,69) = 6.47$, $p < .001$]. The condition by orientation interaction was significant [$F(18,414) = 5.05$, $p < .001$]. Appendix C shows the overall means, standard deviations and standard errors for the test conditions.

Figure 4. Mean identification times for misoriented words as a function of orientation and condition.

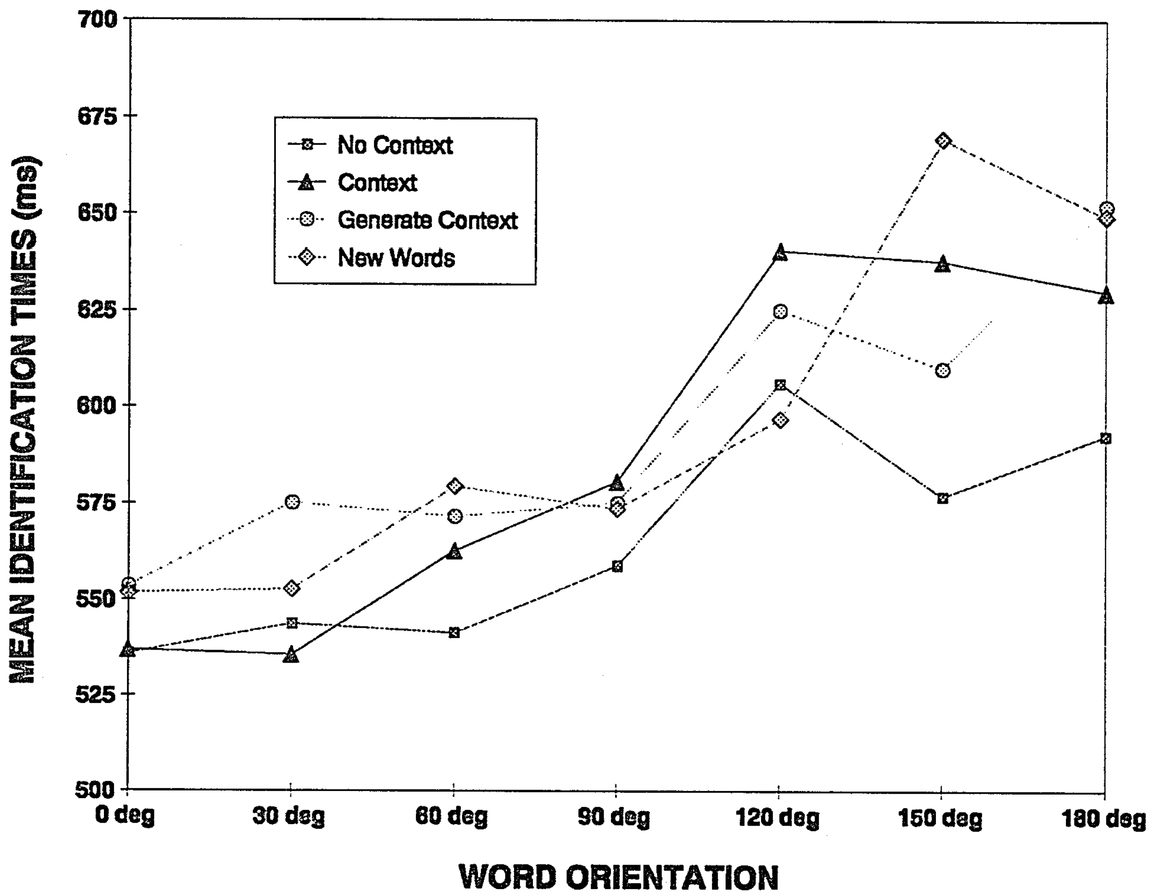
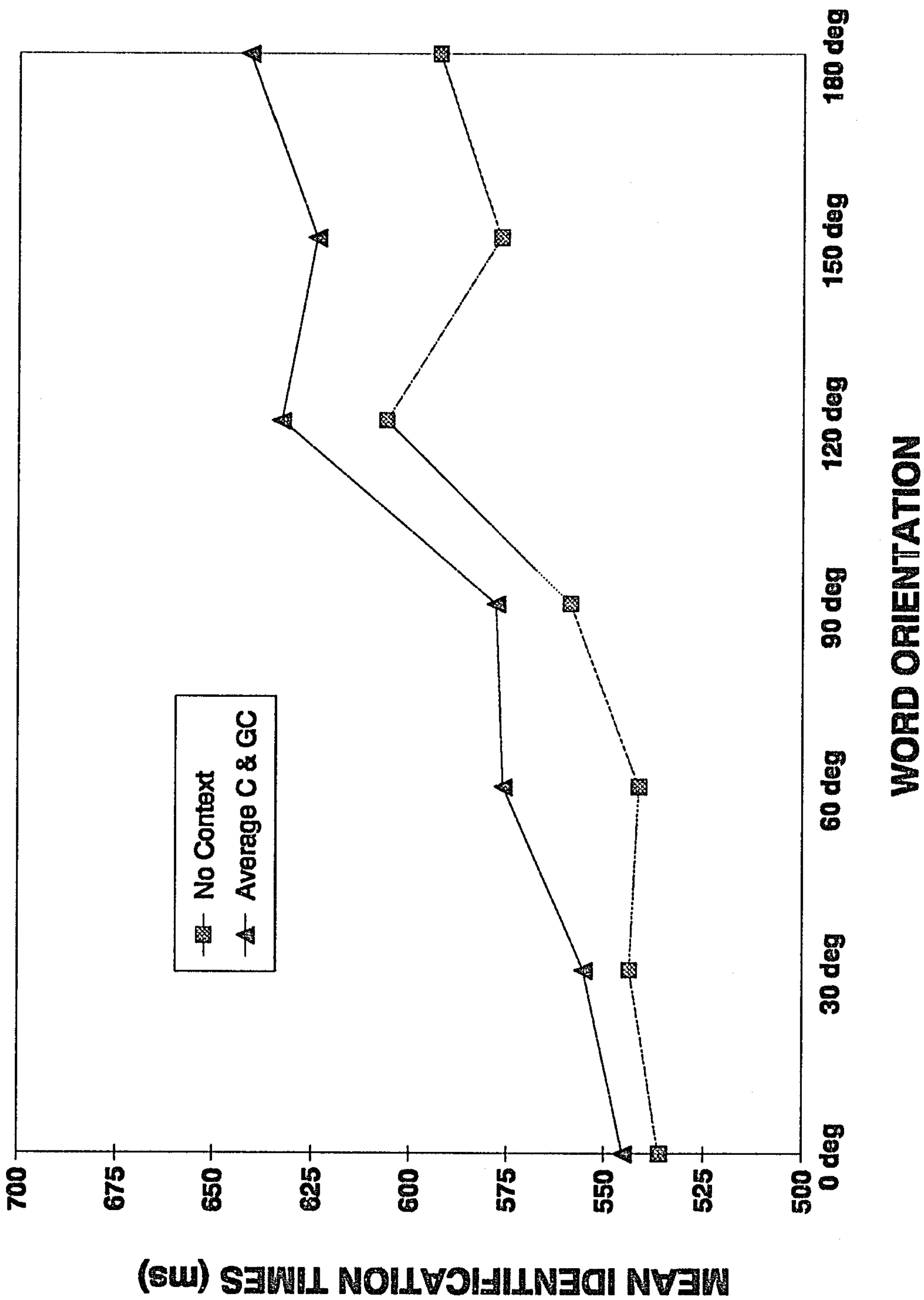


Figure 5. Mean identification times for misoriented words as a function of orientation and condition. (Context and Generate Context combined and compared to No Context)



Increases in response times were slight from 0 deg to 90 deg with a single large increase occurring between 90 and 120 deg and a decrease or flattening thereafter. One minor exception is evident in the control condition which peaked later at 150 deg and then dropped at 180 deg. Condition by orientation interactions occurred for all pairwise comparisons of conditions, except for the comparison between the NO CONTEXT and the GENERATE CONTEXT condition. All of the pairs that interacted were significant at the $p < .001$ level. Response times were fastest for the NO CONTEXT condition. On average, response times were about the same for the control (596.1 ms) and the GENERATE CONTEXT (594.6 ms) conditions, with the CONTEXT condition showing just a slight improvement (589.1 ms). Stimuli from the NO CONTEXT condition was, far and away, the greatest beneficiary of training (565.1 ms). The average overall response time in this experiment (586.2 ms) was rapid in comparison to other word rotation studies.

Identification times yielded in the test phase provide poor evidence that amounts of transformation by mental rotation are directly proportional to word orientation. A linear trend suggesting mental rotation is not evident in the data. Additionally, decreases in response times past 120 deg (or 150 deg in three cases) indicate non-monotonicity. The ordering of these means supports the hypothesis that the degree to which active engagement with the physical stimuli is both possible and necessary during training determines training value. Although this experiment differed in a number of ways from other misoriented word studies, it remains puzzling that response times for short familiar words were so much faster in this case and exhibited a different pattern of orientation effects. The reduced size of the stimulus pool (short, familiar, antonyms vs. the entire lexicon of short, familiar words) may be the source of the difference in response times.

Discussion

There were three principal findings from the present experiment. First, a processing advantage was observed for the condition that lacked contextual information but presented the target word visually. There was no effect of word context observed. Contextual information in training had no clearly discernible effect on an observer's ability to read precued words when they were repeated in non-upright positions. Second, the data did not yield the linear increasing function that indicates mental rotation, but instead appeared dichotomous. Finally, identification response times were considerably faster than those reported for other word rotation experiments. These results will be discussed in turn.

Context versus Perceptual Detail

The NO CONTEXT condition, which displayed the target word uncued, yielded reduced orientation effects in comparison to the other conditions. Without the presence of context, subjects were forced to rely on the visual/perceptual attributes of the target words for identification. This transfer between the training and test trials extended instances of transfer between upright and non-upright stimuli found by Koriat and Norman (1985a) and Jolicoeur and Milliken (1989). This seemed somewhat surprising in regard to the CONTEXT condition because both conditions presented the target word visually. The only difference was that perceptual information was accompanied by contextual information in the form of the antonym cue in the CONTEXT condition. Although the information was as available in the CONTEXT condition as it was in the NO CONTEXT condition, it was not as effective. A reasonable explanation for the presumed lack of exploitation of perceptual information in the CONTEXT condition is that subjects relied heavily on the context cue to guess the upcoming word and thus needed to attend only minimally to the perceptual detail in the word to confirm their guess. Verification of a single letter may have been adequate to make the identification. These results are consistent with Masson's findings regarding the role of visual detail in processing misoriented words.

Another interesting difference between the conditions in terms of perceptual precuing was the pattern of response times at 180 deg. In the GENERATE CONTEXT condition, where subjects did not receive a perceptual precue, the response times peaked at 180 deg and in the conditions where they did, response times were faster at 180 deg than at 120 deg. Since perceptual detail was not available in the generate training condition, subjects may have accessed a representation of the target that was more abstract than one that was activated by perceptual encoding. Processing advantages that ensue from a visually-encoded representation of a misoriented word may not be as equally accessible as those based on abstract properties.

There was no evidence to support the hypothesis that semantic encoding context was effective in reducing response times. No consistent facilitation of response times was observed within the context condition although it was significantly different from the other conditions. The difference was due to variation in response times past 120 deg of angular rotation. There was little difference between the CONTEXT condition and the NO CONTEXT and GENERATE conditions at minor degrees of misorientation (90 deg and under) and all three of the experimental conditions showed a sharp increase in response times from 90 to 120 deg. At orientations greater than 120 deg, the largest amount of divergence between the conditions occurred but the context condition was slower overall than the other two conditions.

The decision to use antonyms to activate higher-level association between cue and target words was based on the results of Jacoby's experiment (1983). There are two reasons why this manipulation may have failed to produce facilitation. First, the type of activation produced may have decayed too rapidly to be effective in the test trials of the experiment. There is evidence to show that activation can be separated into components characterized by different strengths and rates of decay (Scarborough, Cortese, & Scarborough, 1977) and that semantic word priming has a rapid rate of decay with intervening items (Ratcliff, Hockley, & McKoon, 1985). Also, facilitation has been shown to be sensitive to the consistency of strength in semantic relationships (Becker, 1980). Given the ambiguity that exists in the relationship between many antonym pairs, the antonym paradigm may not have been successful in generating regular enough associational context. This could have been the case if the cue antonym member engendered associations that did not encompass its semantic opposite even though subjects were primed to expect an opposite as the target. For instance, the cue word BOY could have activated associates such as active, noisy, or blue. This context may have failed to transfer or may even have interfered with activation surrounding the target word, GIRL. Because of the problems of priming decay rate and consistency of semantic relationship, it would be advisable to run a future study controlling for these two variables. Semantic consistency could be better achieved by using synonyms as cues and targets and priming deterioration could be controlled with a different presentation sequence using synonyms as cues and targets in the same experimental paradigm.

Another possible explanation for the lack of consistent exploitation of context is that it was overshadowed by the availability of salient perceptual information. In other words, the effects of activating a word's contextual associations might only be apparent when there is too little recoverable perceptual information in the misoriented word to allow identification. If this were so, context would be expected to exert influence at orientations where recovery of canonical feature information might be expected to be lowest. It is logical to assume this might be when words are "upside-down" and not aligned with orthogonal axes. Since context did interact with orientation (although erratically) in these positions, this conjecture has some support. It rests, however, on a "strength-of-activation" based model of pattern recognition which will be discussed below.

Nonlinear Function

Although the orientation effects resulting from all four conditions in the experiment were clearly present, they were not indicative of a smooth analog process such as mental rotation. Instead, the data appeared to be essentially dichotomous with minimal increase in identification times from 0 to 90 deg and much larger increases from 90 to 180 deg. This does not follow the usual pattern reported for misoriented words.

Characteristically, words show a monotonically increasing function with non-linearity (flattening of the slope) from 0 to 60 deg and at 180 deg. Flattening in this experiment was extensive (up to 90 deg) and a response time decrease was also present at 150 deg and 180 deg in three conditions. This cannot be explained by appeals to broadtuning or multiple storage as has been done in previous rotation experiments discussed. If the flattening encountered from 0 to 60 deg is accepted as broadtuning, then the extension to 90 deg is left to be explained. One possible explanation is that slope shape is at least partly due to the orientations sampled in this experiment. With the exception of one of Jordan and Huntsman's (1990) experiments, 90 deg was not included in the orientations tested in the word studies previously mentioned. There is evidence from previous studies that orthogonal orientations exhibit a privileged processing status (Kemler, 1983). If the orthogonal status of 90 deg as an external frame of reference is capable of influencing processing of perceptual elements in a misoriented word, then the data in the studies excluding words at 90 deg could have been "smoothed out" in appearance in comparison with a set of orientations including 90 deg. In fact, there was some noticeable flattening present at 90 deg in Jordan and Huntsman's experiment. If elements are being selectively encoded, it is reasonable to expect facilitation at orthogonal positions. This is because the orthogonality of letter features is consistent with the reference frame at these positions. This consistency could affect identification times by reducing disparity in descriptions caused by misoriented elements. For example, letter features that are defined as orthogonal at upright can still be defined as orthogonal at 90 deg. In contrast, the same elements would be described as oblique at 30, 60, 120, and 150 deg. To add to the strength of this argument, 180 deg, which typically exhibits flattening, is also orthogonal.

Another possible reason for the dichotomous appearance of the slope is that the dichotomous nature of the test paradigm (pairs of antonyms) may have suggested a categorical response to the orientation of the words. The data can be interpreted as if the misoriented words were responded to as if they were either "upright" (0-90 deg) or "upside down" (120-180 deg). This line of reasoning is not well supported by previous data but there is an indication (Jolicoeur & Milliken, 1989) that subjects were sensitive to the context of training. They found that upright objects produced facilitation upon repetition at various orientations when they were mixed in practice with non-upright objects but not when they were presented in practice exclusively at upright.

Identification Times

The identification times for all of the conditions were not only faster than response times for mentally rotated stimuli in general, but several hundred milliseconds faster than those recorded for other misoriented word studies (Koriat & Norman, 1989; Jordan & Huntsman, 1990). The average degrees-per-second rotation time reported for misoriented stimuli being compared to an internal representation is between 400 and 500 dps (S. Shepard & D. Metzler, 1988). In this experiment the average (if mental rotation was being claimed) is 1,800 dps. This speed would result in five full 360 deg rotations in 1 s, which is entirely out of the range of any claims made for mental rotation to date. This uncharacteristic function cannot be attributed to practice or priming since it included new words as well as old. There is a possibility that it could have been an artifact of the design. For instance, the presentation of words in the practice phase was different from the other word experiments mentioned. The duration of the 3 s practice sequence may have set up an anticipatory rhythm that heightened attention to the target and decreased response times. This enhanced attention may have then transferred to the test phase.

Alternatively, the source of the differences may lie with the stimulus pool chosen for the experiment (i.e., familiar antonyms). Previous misoriented word experiments conducted by Koriat and Norman (1985b) and Jordan and Huntsman (1990) have used words derived from the entire lexicon of familiar words within the limitations of given letter-string lengths. This represents a much larger stimulus pool than the one used in this experiment. It was, in fact, difficult to generate enough antonym pairs to use in the experiment. If a search for the stored representations of the misoriented words was limited to antonyms, or words that have fewer than four letters and are antonyms, then the decrease in size of the stimulus set to be searched for an appropriate response might have resulted in a decrease in response times. No matter what the driving factor behind the rapid response times, it is most important to note that along with non-linear trends in response times, they render it unlikely that mental rotation was being used to normalize the stimuli.

Theories of Object Recognition

Object recognition poses a problem for theories of visual cognition because sensory objects are viewed in so many different ways. Almost any kind of motion between an observer and an object changes the pattern of stimulation projected onto the retina from a distal stimulus. Edges become blurred, occluded, or lost in shadows as objects are rotated in 3-dimensional space. In picture-plane rotations, stimulus attributes change coordinates in relation to retinal and environmental frames of reference. Many different theories have been proposed to account for recognition, such as template models, feature models, Fourier analysis, and structural descriptions, but all of them run into problems in attempting to account for the entire range of phenomena (see Pinker, 1984). Models that attempt to represent all the variations that stimuli produce in terms of separate patterns have the disadvantage of being unparsimonious. On the other hand, abstract representations do not capture the specifics of any particular object. The task of matching two stimuli that are rotated out of alignment with each other reverts back to the original problem with object recognition; how are two stimuli recognized as identical when they project different patterns of stimulation to the retina? The MR model has circumvented the issue by proposing a special process to align the different views. Only the problem of inequality of orientation has been addressed by the model. The problems of occlusion, shadow, size, and other perceptual inequalities have not been addressed. Although stimuli revolving through the picture plane are equally affected by occlusion or shadow they may be unequal in terms of the ability of the perceptual system to recover their different features. Patterns of results from experiments claiming rotation might be broken down into two groups: functions that are strongly linear and fall within the rate-of-rotation range characteristic of MR and those that are faster and non-linear. Given that the MR model can not account for orientation effects in the second group, these effects deserve to be considered from a point of view outside of the confines of the MR model.

Perceptual Features in Misoriented Words

Early feature detection accounts of recognition of misoriented stimuli (e.g., Selfridge's "Pandemonium" model), have been considered poor candidates for explaining orientation effects because they generally do not specify location and orientation of elements (Pinker, 1984). In addition they don't account for the increase in response times with greater angular departure. Given the important role that features play in mediating orientation effects in this experiment, it is essential to reconsider different ways they could be characterized and processed.

Many features contained in words do not depreciate in their ability to be recognized with misorientation. Local features such as intersections, contour, open and closed circles, and obtuse, acute, and right angles are recognizable no matter what their orientation (Marr, 1982; Marr & Nishihara, 1978; McClelland & Rumelhart, 1981).

These features may be termed orientation invariant (OI) features. Some global features such as overall shape are also orientation invariant. When classifying features as OI it is important to keep in mind that features do not necessarily vary across orientation in an all or none fashion. The amount of variance in description is determined by the combined characteristics of the canonical description of the feature and it's description in a misoriented frame. Some features may vary their descriptions at some orientations but not at others. For instance, vertical and horizontal letter components maintain their descriptions when they are viewed at 180 deg but not at other orientations. Axes that are categorized as orthogonal at a position of 0, 90, 180 or 270 deg are still orthogonal when switched to any other of the remaining three positions. In contrast, other features of words are orientation variant (OV) features. Examples of this feature type are oblique lines which do not maintain their descriptions over change in orientations. These different types of features represent different amounts of information content in a word depending on its angular position.

If OI representations are being extracted in training, then it might be expected that the slope of response times would flatten completely with repetitions at different orientations. However, this is only one possibility. An OI representation may be characterized as impoverished in comparison to an upright one because some perceptual information (i.e., OV information) is missing from it. An ability called visual closure allows an observer to mentally fill in missing parts from an incomplete visual pattern as long as it is familiar, but recognition of the incomplete pattern takes longer as larger portions of it are erased or missing. Applying this reasoning to the task of recognition of misoriented words, it would follow that response time would increase with a decrease in the amount of recoverable perceptual information at each orientation. Other types of perceptual attributes resulting from processing biases for orthogonal positions or upper vs. lower hemisphere, would also be expected to be taken into account if a misoriented recognition task is sensitive to variation in amount of perceptual information. The contributions made by these perceptual attributes at different orientations would not be expected to be equal in amount or in their ratio to angular distance. If feature attributes, like orientation invariance, are taken into account and factored into this already-biased processing space, a new space emerges. Supposing that an exact match between the proximal and the distal stimulus is not necessary and that the pattern accessed in memory is the one that is most consistent with the distal stimulus, then all contributions like those described above would count in the final decision.

Words as Degraded Stimuli

An emphasis on perceptual attributes of misoriented words suggests another way of presenting them, as if they are degraded in comparison to upright. A degraded stimulus is often capable of being recognized, although usually at some cost in comparison to a non-degraded one. The view of a rotated word as degraded is in contrast to the concept of a positionally transformed or misoriented one. A degraded word would be expected to appreciate or depreciate in perceptual value (as determined by the amount of consistency between descriptions of the representation of the word in memory and it's distal misoriented version) as it changes orientations. A transformed word would be expected to remain constant in perceptual value over orientations. In the first case, orientation effects would be attributable to differences in perceptual value and in the second, to a process that is uninvolved with perceptual characteristics. For words, as well as other stimuli, degradation can occur in response to several factors, such as feature type, size, and environmentally-conditioned orientation biases. A discrete stage model like Mental Rotation is not designed to be sensitive to a stimulus that fluctuates in information value as it changes its orientation. However, there are types of models that are designed to accommodate graded changes. These models are known as parallel distributed processing models.

Parallel Distributed Processing Models

The most pertinent properties of parallel distributed processing (PDP) models for this discussion are their strength-based and redundant ones. They account for changes that occur with learning by way of a strengthening process. In these models, "memory for a stimulus or an event is not encoded in a single connection between a generic stimulus and a generic response, but in the strengths of a set of connections involving several different units that are used to provide overlapping but nevertheless distinct representations of individual stimuli and responses" (Cohen, Dunbar, & McClelland, 1990). In this way, PDP models can account for the learning or transfer that takes place over successive exposures to stimuli in rotation experiments by a gradual strengthening of connections within patterns stored in memory and between the distal stimulus and its representation stored in memory. This property of the models allows the perceptual strength associated with memory store to be factored into the perceptually-biased space described above.

In addition to their general ability to represent transfer observed in word rotation experiments, PDP models lend themselves to explanations of the feature specific character of misoriented stimulus resolution. Redundancy of representation involved in interconnected units allows for the value of stimulus (or word in this case) features to be assessed individually or as a group. A weighting scheme sets up a flexible, hierarchical organization of features. This plastic representation of features accommodates the general feature-driven results observed in this study as well as the more feature specific ones encountered by Masson (1986) in his experiment with typographically transformed words. In addressing Masson's results, it is appropriate to emphasize that the redundant properties of PDP systems allow for capture and representation of specific detail of an encountered stimulus but predict decay with intervening non-identical activation to the set of representing connections. For the sake of delineating potentials and predictions of two very different types of models, a comparison between the processing and predictions of a discrete stage, mental rotation model and a PDP model may be helpful.

Comparison of Processing Models

The two ways of characterizing non-upright words previously mentioned (i.e., as transformed or degraded) divide nicely into two types of models which are outlined in Table 1. Many of the assumptions and characteristics of the serial analog, discrete stage, mental rotation model have already been discussed. It is important to note, however, that the speed and efficiency of the process outlined in this model may be less than a process that acts selectively and in a parallel fashion on partial input. Also, note that the type of processing required is likely to change with the task because any task that requires discrimination of orientation for its completion cannot be accomplished by discrimination of features alone. Mirror-image and left/right discriminations demand that reference frames be taken into account while many other types of stimulus discriminations and decisions do not. In some cases, processing demands do not divide clearly by task. For

Table 1. Comparison of Processing Models

Character of Processing:

Example of model type	Mental Rotation	Interactive Activation
Stimulus condition	Misoriented	Degraded
Focus of operation	Orientation	Perceptual detail
Process	Transformation (intact)	Resolution (components)
Resulting function	Smooth, analog	Variable (with sum total of degradation)
Task applications	Orientation discrimination	Identification *
	Left/Right discrimination	Recognition (old/new) *
	Mirror image discrimination	Same/Different*
	Axis matching	Categorization *

* These tasks would not necessarily require a transformation for orientation except in the case where the task called for an orientation discrimination. An example would be the rotated cube drawings in Shepard and Metzler's 1971 experiment. These shapes were essentially identical in perceptual detail when they matched. Since they only differed along the dimension of orientation, orientation information had to be recovered in order to do the matching task. In cases such as these, it is noteworthy that "different" responses are faster than "same" responses. The non matching figures were necessarily discriminable along the dimension of perceptual detail.

instance, same/different judgments may require orientation discrimination if they do not provide enough accessible perceptual information to be easily discriminated along some other dimension. This could be the case with identical rotated block figures or in outline depictions of real objects that are already degraded at upright in comparison to their memory stored referents (e.g., those used by Jolicoeur & Milliken, 1989). The second, PDP, model type differs from the first model type in that it is graded and continuous in action as opposed to absolute and discrete. Since the processing of stimulus attributes goes on in parallel, it predicts relatively rapid resolution that varies with information encoded from the distal (word) stimulus. The function resulting from processing would be expected to vary with word and other related perceptual attributes rather than be systematically increasing with angular departure. Because PDP does not depend on separate storage to distinguish stimulus differences, it builds in aspects of competition (for connective pathways) as well as a hierarchical representation of features that is established through combinations of factors like recency, specificity, and frequency of pathway activation. All of these properties would be expected to factor into response times to make decisions about misoriented word.

An example of a PDP model that was designed to explain the recognition of words from feature elements is the Interactive Activation (IA) model proposed by Rumelhart and McClleland (1982). In this model, word identification is treated as an interactive process wherein the processing of any letter in a multiletter display takes place with and is affected by the context of ongoing processing of all the other letters. "Thus as the activation grows within one letter it serves to facilitate the perception of the surrounding letters" (Rumelhart & McClelland, 1982). This description of perceptual processing amounts to a gradual building of perceptual information based on the original encoding. Instead of being separable and static in action, stimulus elements and properties in this model are depicted as dynamic. Since their influence is not active all at once, it follows that overall processing time would be lengthened by missing (degraded) information. It also predicts that bits of perceptual information would be increasingly available on a gradual basis before reconstruction is complete. This suggests an alternate way to account for orientation effects; in terms of costs due to reconstructing a word from less than the amount of information available at its canonical orientation.

There are strengths and weaknesses associated with both of the models discussed as they are applied to making decisions about misoriented words. Mental Rotation does not explain non-linear results and PDP does not provide a strong rationale for linear results. These problems could be resolved by assuming that the models describe flexible strategies that are selected according to task demands or determined according to individual spatial ability. Mental rotation is a very appealing model when used to explain linear increasing functions but it may be in danger of being overextended in addressing many instances of misoriented stimulus recognition.

Implications for a Representational Mechanism

The indication that the amount or quality of perceptual information recovered from a misoriented stimulus is a factor in driving orientation effects is very intriguing. There may be other stimulus properties that will be found effective as well. As more research is undertaken to determine factors contributing to orientation effects, more clues to the nature of mental representations in general promise to be uncovered.

References

Becker, Curtis A. (1980). Semantic context effects in visual word recognition: An analysis of semantic strategies. Memory & Cognition, 8 (6), 493-512.

Bethell-Fox, C. E., & Shepard, R. N. (1988). Mental rotation: Effects of stimulus complexity and familiarity. Journal of Experimental Psychology: Human Perception and Performance, 14, 12-23.

Biederman, I. (1987). Recognition-by-components: A theory of human image understanding. Psychological Review, 94, 115-147.

Cohen, J., Dunbar, K. & McClelland, J. (1990). On the control of automatic processes: A parallel distributed processing account of the stroop effect. Psychological Review, 97 (3), 332-361.

Cooper, L. A. (1976). Demonstration of a mental analog of an external rotation. Perception & Psychophysics, 19, 296-302.

Cooper, L. A., & Podgorny, P. (1976). Mental transformations and visual comparison processes: Effects of complexity and similarity. Journal of Experimental Psychology: Human Perception and Performance, 2, 503-514.

Cooper, L. A & Shepard, R. N. (1973). Chronometric studies of the rotation of mental images. In W. G. Chase (Ed.), Visual information processing (pp. 75-176). New York: Academic Press.

Corballis, M. C., & Cullen, S. (1986). Decisions about the axes of disoriented shapes. Memory & Cognition, 14 (1), 27-38.

Corballis , M. C., & Nagourney, B. A. (1978). Latency to categorize disoriented alphanumeric characters as letters or digits. Canadian Journal of Psychology, 32 (3), 186-188.

Craik, F. I. M., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. Journal of Verbal Learning and Verbal Behavior, 11, 671-684.

Craik, F. I. M., & Tulving, E. (1975). Depth of processing and the retention of words in episodic memory. Journal of Experimental Psychology: General, 104, 268-294.

Hock, H. S. & Tromley, C. L. (1978). Mental rotation and perceptual uprightness. Perception & Psychophysics, 24, 529-533.

Jacoby, L. L. (1983). Remembering the data: Analyzing interactive processes in reading. Journal of Verbal Learning and Verbal Behavior, 22, 485-508.

Jolicoeur, P. (1985). The time to name disoriented natural objects. Memory & Cognition, 13, 289-303.

Jolicoeur, P. & Landau, M. J. (1984). Effects of orientation on the identification of simple visual patterns. Canadian Journal of Psychology, 38, 80-93.

Jolicoeur, P. & Milliken, B. (1989). Identification of disoriented objects: Effects of context of prior presentation. Journal of Experimental Psychology: Learning, Memory, and Cognition, 15 (2), 200-210.

Jordan, K. & Huntsman, L. A. (1990). Image rotation of misoriented letter strings: Effects of orientation cuing and repetition. Perception & Psychophysics, 48, 363-374.

Jordan, K. & Huntsman, L. A. (1991). String length and repetition affect lexical decisions about disoriented letter strings. Paper presented at the annual meeting of the Psychonomic Society, San Francisco.

Koriat, A. & Norman, J. (1985a). Mental rotation and visual familiarity. Perception and Psychophysics, 37, 429-439.

Koriat, A. & Norman, J. (1985b). Reading rotated words. Journal of Experimental Psychology: Human Perception and Performance, 11, 490-508.

Koriat, A. & Norman, J. (1988). Frames and images: Sequential effects in mental rotation. Journal of Experimental Psychology: Human Perception and Performance, 14, 93-111.

Koriat, A., & Norman, J. (1989). Establishing global and local correspondence between successive stimuli: The holistic nature of backward alignment. Journal of Experimental Psychology: learning, Memory, and Cognition, 15 (3), 480-494.

Marr, D. (1982). Vision: A Computational Investigation into the Human Representation and Processing of Visual Information. San Francisco: Freeman.

Marr, D. & Nishihara, H.K. (1978). Representation and recognition of the spatial orientation of three-dimensional shapes. Proceedings Royal Society of London. B, 200, 269-294.

Masson, M. (1986). Identification of typographically transformed words: Instance-based skill acquisition. Journal of Experimental Psychology: Learning, Memory, and Cognition, 12, 479-488.

McClelland, J. L., & Rumelhart, D. E. (1981). An interactive activation model of context effects in letter perception: Part I. An account of basic findings. Psychological Review, 88, 375-407.

Pinker, S. (1984). Visual Cognition: An introduction. Cognition, (18), 1-63.

Robertson, L. C., & Palmer, S. E. (1983). Holistic processes in the perception and transformation of disoriented figures. Journal of Experimental Psychology: Human Perception and Performance, 9, 203- 214.

Scarborough, D. L., Cortese, C., & Scarborough, H. (1977). Frequency and repetition effects in lexical memory. Journal of Experimental Psychology: Human Perception and Performance, 3, 1-17.

Shepard, R. N., & Cooper, L. A. (1982). Mental images and their transformations. Cambridge, MA: The MIT Press.

Shepard, S. & Metzler, D. (1988). Mental rotation: Effects of dimensionality of objects and type of task. Journal of Experimental Psychology: Human Perception and Performance, 14(1), 3-11.

Tarr, M. J. & Pinker, S. (1989). Mental rotation and orientation-dependence in shape recognition. Cognitive Psychlogy, 21, 233-282.

White, M. J. (1980). Naming and categorization of tilted alphanumeric characters do not require mental rotation. Bulletin of the Psychonomic Society, 15 (3), 153-156.

Yuille, J. C., & Steiger, J. H. (1982). Nonholistic processing in mental rotation: Some suggestive evidence. Perception & Psychophysics, 31, (3), 201-209.

Appendix A

Signed Approval Forms

Design and Analysis Approval Form

Human Subject Approval Form

SJSU SAN JOSE STATE UNIVERSITY

A campus of The California State University

College of Social Sciences • Department of Psychology
One Washington Square • San José, California 95192-0120 • 408/924-5600 • FAX 408/924-5605

November 25, 1991

TO: Susanne Delzell, MA candidate

FROM: Kevin Jordan, MA Coordinator

RE: Design and analysis review

Drs. Alvarez and Wise have read your thesis proposal for the Design and Analysis Committee. Their comments are enclosed. Based on their comments, the thesis proposal is approved. As you can see, neither reviewer has serious concerns. However, Dr. Alvarez has a few comments concerning the description of the experiemntal design which merit your careful consideration. Specifically, you need to make clear that while there are three training conditions, there are four conditions in the test phase due to the inclusion of a set of new word controls.

Based on this committee's approval, the collection of data for your thesis is approved contingent on documentation of compliance with university policy regarding the use of human subjects in research. University policy requires approval of your project by the Human Subjects Institutional Review Board. Please provide me with a file copy documenting such approval as soon as you receive it. After that copy is part of your file, you may begin collecting data.

Congratulations on your progress to date! We look forward to the continuation of your fine performance in the program.

cc:
Alvarez
Cooper
Johnson (NASA-ARC; forward to Jordan)
Jordan
Wise
file

SJSU SAN JOSE STATE UNIVERSITY

A campus of The California State University

Office of the Academic Vice President • Associate Academic Vice President • Graduate Studies and Research
One Washington Square • San José, California 95192-0025 • 408/924-2480

To: Susanne R. Delzell, Psychology
744 Rosewood Drive
Palo Alto, CA 95303

From: Charles R. Bolz
Office of Graduate Studies and Research

Date: February 26, 1991

Charles R. Bolz

The Human Subjects Institutional Review Board has approved your request to use human subjects in the study entitled:

"The Effects of Context on Reading Misoriented Words"

This approval is contingent upon the subjects participating in your research project being appropriately protected from risk. This includes the protection of the anonymity of the subjects' identity when they participate in your research project, and with regard to any and all data that may be collected from the subjects. The Board's approval includes continued monitoring of your research by the Board to assure that the subjects are being adequately and properly protected from such risks. If at any time a subject becomes injured or complains of injury, you must notify Dr. Serena Stanford immediately. Injury includes but is not limited to bodily harm, psychological trauma and release of potentially damaging personal information.

Please also be advised that each subject needs to be fully informed and aware that their participation in your research project is voluntary, and that he or she may withdraw from the project at any time. Further, a subject's participation, refusal to participate or withdrawal will not affect any services the subject is receiving or will receive at the institution in which the research is being conducted.

If you have any questions, please contact Dr. Stanford or me at (408) 924-2480.

cc: Kevin Jordan, Ph.D.

Appendix B

Antonym Pairs Table

	CUE	TARGET	CUE	TARGET	CUE	TARGET	CUE	TARGET
1	sit	**stand**	hit	**miss**	quiet	**loud**	go	**stop**
2	expensive	**cheap**	virtue	**vice**	boy	**girl**	courage	**fear**
3	end	**begin**	succeed	**fail**	rich	**poor**	valley	**peak**
4	odd	**even**	sinner	**saint**	float	**sink**	small	**large**
5	there	**here**	meek	**bold**	thick	**thin**	hot	**cold**
6	tame	**wild**	seek	**hide**	pride	**shame**	under	**over**
7	pleasure	**pain**	dirty	**clean**	master	**slave**	stale	**fresh**
8	future	**past**	close	**open**	gain	**loss**	captive	**free**
9	before	**after**	quick	**slow**	finish	**start**	common	**rare**
10	real	**fake**	polite	**rude**	short	**tall**	top	**base**
11	south	**north**	play	**work**	empty	**full**	excited	**calm**
12	alive	**dead**	lift	**drop**	early	**late**	earlier	**later**
13	dull	**sharp**	came	**went**	part	**whole**	all	**none**
14	bitter	**sweet**	spend	**save**	buy	**sell**	spicy	**mild**
15	mend	**break**	strong	**weak**	silence	**sound**	drop	**hold**
16	straight	**bent**	east	**west**	leave	**stay**	foul	**fair**
17	narrow	**wide**	pull	**push**	back	**front**	conserve	**waste**
18	right	**left**	husband	**wife**	day	**night**	follow	**lead**
19	hate	**love**	humble	**proud**	crazy	**sane**	old	**young**
20	found	**lost**	different	**same**	long	**short**	give	**take**
21	first	**last**	soft	**hard**	least	**most**	run	**walk**
22	fiction	**fact**	true	**false**	low	**high**	curse	**bless**
23	learn	**teach**	credit	**cash**	up	**down**	lie	**truth**
24	entertain	**bore**	dumb	**smart**	lower	**raise**	suspicion	**trust**
25	other	**self**	life	**death**	bad	**good**	villain	**hero**
26	cruel	**kind**	ceiling	**floor**	sick	**well**	coarse	**fine**
27	light	**dark**	joy	**grief**	shallow	**deep**	war	**peace**
28	messy	**neat**	whisper	**shout**	warm	**cool**	sleep	**wake**

Appendix C

ANOVA Summary Table

SOURCE: Grand Mean

Condition	Orientation	N	Mean	SD	SE
		672	586.2227	104.7638	4.0414

SOURCE: Condition

Condition	Orientation	N	Mean	SD	SE
1		168	565.0517	96.3996	7.4374
2		168	589.1096	110.0708	8.4921
3		168	594.5955	102.7848	7.9300
4		168	596.1339	107.2250	8.2726

SOURCE: Orientation

Condition	Orientation	N	Mean	SD	SE
	2	96	551.8238	100.4782	10.2550
	5	96	617.1208	106.5952	10.8793
	1	96	544.5083	84.0378	8.5771
	4	96	572.0599	88.9785	9.0813
	7	96	630.8417	144.2890	11.6646
	6	96	623.5174	105.1145	10.7282
	3	96	563.6870	94.4473	9.6395

SOURCE: Condition by Orientation

Condition	Orientation	N	Mean	SD	SE
1	2	24	543.7326	91.1130	18.5984
1	5	24	606.1375	114.9251	23.4590
1	1	24	536.0333	86.5086	17.6585
1	4	24	558.8229	88.0602	17.9752
1	7	24	592.5729	96.4587	19.6896
1	6	24	576.7812	93.8327	19.1535
1	3	24	541.2812	89.1035	18.1882

2	2	24	535.7187	105.7329	21.5826
2	5	24	640.4500	118.1820	24.1238
2	1	24	536.8542	97.1020	19.8209
2	4	24	580.7083	106.1043	21.6584
2	7	24	629.7604	105.0724	21.4478
2	6	24	637.6736	90.5957	18.4928
2	3	24	562.6021	90.5505	19.7083
3	2	24	575.1042	106.0363	21.6446
3	5	24	625.1146	108.2821	22.1030
3	1	24	553.4583	73.1187	14.9253
3	4	24	575.1146	87.5091	17.8627
3	7	24	651.8562	125.9988	25.7194
3	6	24	610.0000	94.0052	19.1887
3	3	24	571.5208	90.9320	18.5614
4	2	24	552.7396	100.3506	20.4840
4	5	24	596.7812	82.7059	16.8823
4	1	24	551.6875	81.4753	16.6311
4	4	24	573.5937	75.8796	15.4889
4	7	24	649.1771	124.0582	25.3233
4	6	24	669.6146	122.0323	24.9097
4	3	24	579.3437	102.3217	20.8863

SOURCE

	SS	df	MS	F	P	
mean	230937535.0831	1	230937535.0831	1087.7990	0.0000	***
s/	4882854.9289	23	212298.0404			
condition	104908.3402	3	3493.4467	6.4730	0.0010	***
cs/	372992.9119	69	5405.6944			
orientation	764952.5836	6	127492.0973	38.9810	0.0000	***
os/	451342.9080	138	3270.6008			
cond x orien	141724.9755	18	7873.6098	5.0480	0.0000	***
cos/	645681.5827	414	1559.6173			