ABSTRACT

STOKES, THOMAS ALLEN. Distinctiveness, Memory and Duration Perception: A Comparison of Feature-Based and Categorical Distinctiveness' Effect on Memory and Perceived Duration. (Under the direction of Douglas J. Gillan.)

Distinctive events—events that are different than those occurring in the same set due to violation of prevailing context—seem to receive preferential processing from the human attentional system. Distinctive events and stimuli have been shown to lead to greater perceived durations, higher recognition and recall rates, and greater likelihood to produce an attention orienting response. Research on distinctiveness' effect on memory (see the isolation effect) and time perception (see the oddball effect) seem to agree that the root cause of each is tied to heightened attention to the distinctive item. To this point research on distinctiveness explored its effects on memory and perceived duration separately—the experiments presented in this paper combine the experimental paradigms of the oddball and von Restorff effects to explore these distinctiveness effects simultaneously. In addition to exploring the relationship between these effects on memory and perceived duration, the experiments provide methods for empirically varying degree of distinctiveness for experimental stimuli, and explore the differences between stimuli that are distinct by their perceptual features, and those that are categorically distinct. Results show that, generally, responses in memory and time perception are similar to manipulations of distinctiveness. However, there is little evidence that a subject's response to distinctiveness in terms of time perception is associated with their response in terms of odds to remember a stimulus. Additionally results show that there is an important distinction between the stimuli types used (feature and categorical)—stimuli that are distinct by their features imposed a working memory load which resulted in a two-phase relationship where moderate levels of distinctiveness increase time perception and

memory, however higher levels caused the trend to reverse. For categorically distinct stimuli there was no evidence of a working memory load, and any reasonable degree of distinctiveness yielded a (relatively equal) increase in memory and time perception, forming a fairly asymptotic relationship.

Distinctiveness, Memory and Duration Perception: A Comparison of Feature-Based and Categorical Distinctiveness' Effect on Memory and Perceived Duration

by
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BIOGRAPHY

Thomas Allen Stokes was born in Raleigh, North Carolina where he was raised by his parents, Michael T. Stokes, and Sabrina M. Stokes. Thomas received a B.A. in Psychology in 2013, and enrolled in the Human Factors and Applied Cognition program the following fall, working under the guidance of Dr. Doug Gillan.

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INTRODUCTION

Distinctive events seem to receive preferential processing from the human attentional system. For the purposes of this research we will define distinctive events or stimuli as those that are different from others within the same set due to violations of the prevailing context. For example, imagine a list of contact cards with phone numbers except one distinctive card that has the person's email address—or another example could be a picture of a landscape in a slideshow full of family portraits. Distinctiveness' effect on attention and cognition has been well documented. Most notably, distinctive events and stimuli have been shown to lead to greater perceived durations, higher recognition and recall rates, and greater likelihood to produce an attention orienting response (Eagleman, 2008; Stetson, Fiesta, & Eagleman, 2007; von Restorff, 1933). In other words, distinctive objects and events are better remembered and seem to last longer (relative to actual duration) than less distinctive things. In the contact list example above, you would likely remember the person's name with the email listed on their contact over those with phone numbers, and for the slideshow example it may seem as though the landscape photo was on screen longer than the rest, even if it was displayed for as long as the rest of the photos.

Von Restorff (1933) is credited with being the first to publish on the link between distinctiveness and memory. Von Restorff used a paradigm whereby lists of items (nonsense words, regular words, objects, etc.) were presented to subjects; the lists would contain one item that contextually stood out from the rest. For example, she might present a string of letters in a list of digits, or a green stimulus in a set of otherwise orange stimuli. Using this isolation paradigm, von Restorff found that subjects generally remembered the distinctive item better than the other, similar items in the lists. This finding, termed the isolation effect (i.e., enhanced memory for distinctive item in a set), has been replicated in a number of different contexts, including use of different stimuli in the list, memory testing conditions, and lists presentation type (e.g., sequential presentation of list items or full-list display) (see examples: Bird, 1980; Bruce & Gaines, 1976; Parker, Wilding, & Akerman, 1998; Rundus, 1971; Saul & Osgood, 1950; Siegal, 1943).

In addition to increased memory likelihood, distinctive events have an effect on time perception whereby distinctive stimuli or events appear to dilate perceived duration. For example, in the oddball effect, events that are novel, unexpected, or differ from the prevailing context can lead to a dilation of time perception for that event or contraction of other less distinctive events around it in a sequence, leading to greater perceived durations (Eagleman, 2008; Pariyadath & Eagleman, 2007; Stetson, Fiesta, & Eagleman, 2007). Additionally, research shows that in trains of similar visual stimuli, after as few as two to three similar stimuli are presented, enough of a context is set so that following stimuli that are similar to the initial stimuli receive compressed time perception ratings, whereas a distinctive stimulus that differs from the prevailing context set by the first few stimuli results in longer reported perceived durations (Pariyadath & Eagleman, 2007; Rose & Summers, 1995).

The theories behind distinctiveness' increase on memory and perceived duration share similar explanations; many theories argue that greater attention to the distinctive item plays a significant role. In memory research, the prevailing argument is that increased attention to the distinctive item in the isolation paradigm accounts for the von Restorff effect, and the cause of the increased attention is some combination of violating the context set by the non-distinctive items and perceptual salience (Green, 1956; Rundus, 1971; Schmidt, 1991). Similarly, theories behind increased duration perception rely on attentional explanations. Generally speaking, dilations in time perception are explained by differences in attention (see examples: Gibbon, 1977; Gibbon, Church, & Meck, 1984; Thomas & Weaver, 1975; Treisman, 1963; Tse et al., 2004, van Wassenhove et al., 2008). Many theories propose that an internal, clock-like mechanism creates pulses and possesses a way to track these pulses. Further, the number of pulses that accumulate during a given event influences our time perception (Gibbon, 1977; Gibbon, Church, & Meck, 1984). From this theory, time dilations are attributed to a heightened state of arousal or attention to events; by which heightened arousal increases the frequency of pulses. This increased pulse frequency means that the distinctive event is judged to be longer relative to less arousing events of the same actual duration. More specifically, duration perception for distinctive events and stimuli have been shown experimentally vary by attention allocation; Tse et al. (2004) noted that subjective time does not expand for distinctive stimuli if they appear for a duration shorter than what is needed for explicit attention to visual stimuli.

Due to their similarities, we believe that distinctiveness' effect on memory and time perception may be strongly related, or even share similar cognitive mechanisms. With this in mind one of the primary goals of this research is to determine whether memory and time perception are similarly responsive to manipulations in distinctiveness. However, one problem with comparing memory and duration perceptions' responsiveness to manipulations in distinctiveness is that in previous experimental paradigms distinctiveness has not typically been manipulated along a continuum (see Examples: Eriksen, 1963; Gumenik & Levitt, 1968; Kimble & Dufort, 1955). Rather, one commonly sees isolation paradigm sets that have a distinctive stimulus that has not been operationally measured against the prevailing context it is placed in—for example a string of letters inside a list of digits or a square in a set of ovals are both distinctive however there is little to no effort to quantify this level of distinctiveness. In addition to not addressing the level of distinctiveness there also seems to be two different types of distinctive stimuli that are used interchangeably; some are distinct by their perceptual features (i.e. separable properties of stimuli that are processed by selective receptors) (Treisman & Gelade, 1980) while others are more conceptually distinct and fit into different categories due to their relationships rather than their physical features. To address these shortcomings the second primary goal of this research is to develop and test a more systematic way of operationalizing feature and categorical distinctiveness that affords measurement along a scale (rather than measuring distinctiveness as a binary construct).

One approach to quantifying degree of feature distinctiveness would be to apply Tversky's (1977) feature-matching theory. In this framework the similarity of two stimuli (A and B) is a function of: the shared features of A and B, features that belong to A but not B, and features that belong to B but not A. Using this framework stimuli will be developed to systematically vary by their level of distinctiveness within a set (described later in the method section of Experiment 1A) and validated through subjective scoring. For conceptual distinctiveness there is no conceptual framework or formula that gives a measure of how different two members of different categories are. While there is no formulaic framework to turn to, previous research on similarity has established methods (Dunlap & Grabinger; Schvaneveldt, 1990) for determining the relative psychological distance between concepts and ideas. Using subjective ratings and algorithms (e.g., Pathfinder) one can reliably represent knowledge structures, which can be adapted to quantify the distinctiveness between categorical stimuli.

Once measures of feature and categorical distinctiveness are derived their effects on perceived duration and recognition memory will be tested using a paradigm (described in Experiments 1B and 2B) adapted from what is commonly used in research on the oddball and von Restorff effects. We hypothesize that (both categorical and feature-based) distinctiveness will have a significant, positive impact on both memory and duration perception. We also predict that memory and duration perception will be, in some level, similarly responsive to manipulated distinctiveness. Finally, we predict that level of attention paid to the stimuli will increase distinctiveness' effects on memory and time perception, which will be observable through a distinctiveness by stimulus duration interaction.

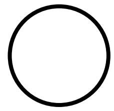
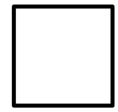
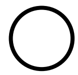
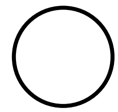
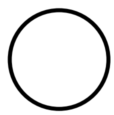
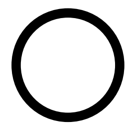
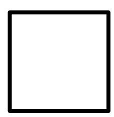
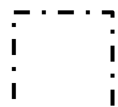
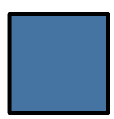
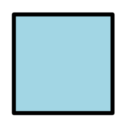
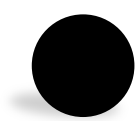
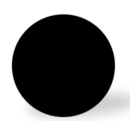
EXPERIMENT 1A: SUBJECTIVE DISTINCTIVENESS RATINGS OF FEATURE-MANIPLUATED STIMULI

Method

Experimental Stimuli & Features

The stimuli used in Experiments 1A and 1B were basic shapes, manipulated along a set number of perceptual features. To keep the complexity of the stimuli equal the features were not distinctive by their presence or absence, rather each general feature could take one of two specific values. Each individual stimulus varied along the following seven general features; shape, size, gradient, outline size, outline pattern, color, and shadow. Examples of each of these features and their possible values can be seen in Table 1, and an example of two completely distinct stimuli (differing on all features) can be seen in Figure 1. In all, this combines to 256 different, multi-feature stimuli that were placed into experimental trials.

Table 1. Features Used in Experimental Stimuli.

Feature	Values	
Shape	Circle 	Square 
Size	Small 	Large 
Gradient	Radial 	Angular 
Outline Size	Thin 	Thick 
Outline Pattern	Solid 	Dashed 
Color	Blue 	Light Blue 
Shadow	Left 	Right 

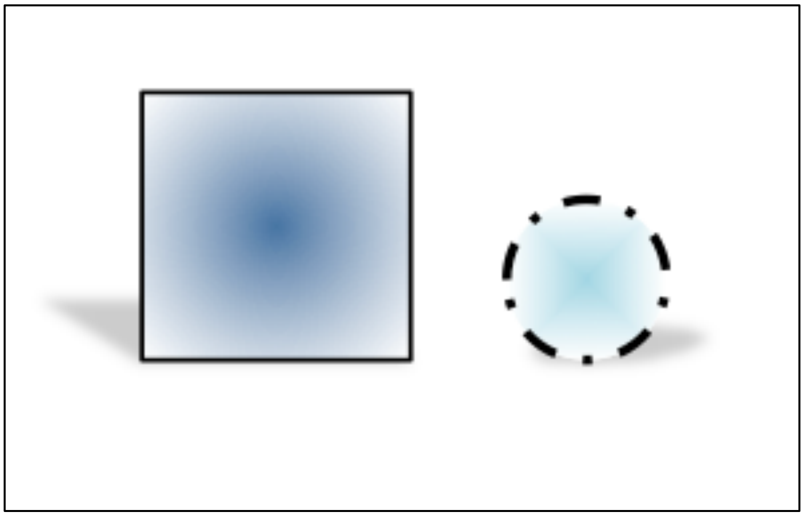


Figure 1. Example of two stimuli varying in all features.

Distinctiveness Ratings.

Recall that similarity of two objects A and B, according to Tversky (1977), is a function of the total shared features of A and B, the features that A has that B does not, and the features that B has that A does not. Since all the stimuli have the same set of seven general features they can be described by their number of shared features, or by their number (out of seven) of features where they differ. The number of different features between two stimuli will serve as our operational definition of feature distinctiveness in this experiment. One potential problem with this definition of feature-distinctiveness is that the Tversky model does not account for possible differences in the relative salience of features that make up the object. For example, one might find that the color or shading of an object is more salient than the thickness of its outline. To account for this a rating study was run in Experiment 1A wherein subjects rated the distinctiveness of the experimental stimuli. Having subjective ratings may help account for unequal salience of the features used in the experimental stimuli (if they exist) and better represent the psychological experience of distinctiveness.

During the experiment, participants viewed pairs of stimuli taken from the set described above. For each pair of stimuli participants were asked to rate the degree to which they see the two stimuli as distinct from one another on a scale from 1 to 10. The stimuli pairings were either identical, or differ by one, three, five or seven features. In total, subjects made 200 comparisons (40 observations per level [5] of shared features).

Presentation Conditions

To investigate potential differences in perceived distinctiveness due to viewing method two separate presentation types were used. One sample of subjects viewed the pairs of stimuli sequentially. In this condition stimulus 1 would appear for a short duration, then there would be an interstimulus interval, then stimulus 2 would be displayed, then participants would give their distinctiveness rating (with neither stimuli on-screen). In the other condition subjects would view the two stimuli simultaneously and responded with their distinctiveness ratings while both were on-screen. The purpose of investigating both of these conditions was to observe whether the distinctiveness between two stimuli would differ if the comparison was made from memory, or while directly perceiving each.

Participants & Recruitment

Participants for Experiment 1A were recruited through Amazon's Mechanical Turk and compensated $1.50 for participating. All participants were required to be at least 18 years of age, have a lifetime M-Turk approval rating of at least 95%, have normal or corrected-to-normal vision, and speak English with enough proficiency to understand the language of the consent form and instructions given during the experiment.

In total fifty-three subjects volunteered for the experiment. Of these 53, seventeen were assigned to the sequential presentation condition, and thirty-six were assigned to simultaneous presentation. Demographics for the overall sample and for each condition are given in Table 2 below.

Table 2. Sample Demographics for Experiment 1A

	Condition					
	Sequential		Simultaneous		Total Sample	
Gender	Frequency	Percent	Frequency	Percent	Frequency	Percent
Male	10	(62%)	11	(48%)	21	(53%)
Female	6	(38%)	12	(52%)	18	(47%)
Age						
18-25	1	(6%)	4	(13%)	5	(11%)
26-35	5	(32%)	13	(43%)	18	(39%)
36-45	5	(32%)	8	(26%)	13	(43%)
46-55	2	(13%)	3	(10%)	5	(17%)
56+	3	(19%)	2	(6%)	5	(17%)
Education Level						
High school	3	(19%)	5	(16%)	8	(17%)
Some college	5	(32%)	7	(23%)	12	(26%)
2-year degree	3	(19%)	3	(10%)	6	(13%)
4-year degree	5	(32%)	12	(40%)	17	(37%)
Graduate degree	0	(0%)	2	(7%)	2	(4%)

Note: Some participants opted-out of answering demographic questions. Percentages are given out of total responses.

Results

The primary analysis of interest was to observe the relationship between the number of different features in a stimuli pair and the distinctiveness rating given. For both presentation conditions, distinctiveness ratings increased linearly as a function of the number of different features between the stimuli in the rating pair (R^2= .988 and .971 for the simultaneous and sequential conditions respectively). Figure 2 shows the linear relationship along with lines-of-best fit for both rating conditions.

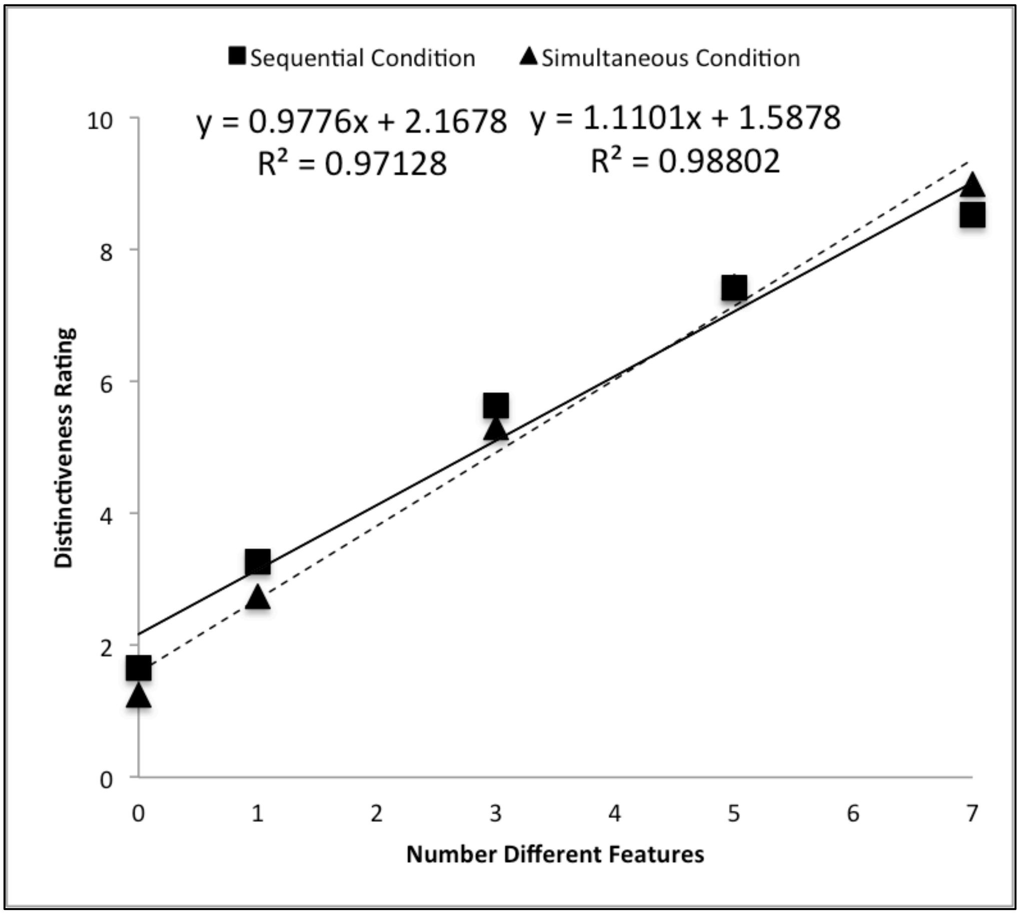


Figure 2. Distinctiveness rating as a function of number of different features.

The two trend lines are roughly the same in terms of their equation, and a Fisher's r to z transform reveals that the relationships for the two rating conditions were not significantly different from one another (Z= .01, p= .999). Taken together, these analyses show that: (1) the relationship between number of different features and perceived distinctiveness is linear in nature, and (2) the relationship [between rating and number of different features] does not change depending on whether the subject viewed the stimuli while giving their rating, or if they make their comparison from mentally held representations of the stimuli.

In addition to assessing the effect of raw number of different features on perceived distinctiveness, the research also centered around ensuring that each individual feature (e.g., shape, color, etc.) significantly contributed to the perceived levels of distinctiveness by observing the relative strength of the individual features. Using dummy-coded variables representing difference for each of the seven features (e.g., 0=same shape, 1=different shape) a regression predicting perceived distinctiveness was run. Each of the seven features were statistically significant individual predictors in the model (all $p < .01$). Further, each of the standard β coefficients were within a range of .13 of each other, suggesting that each feature's effect on the outcome distinctiveness rating was roughly equal. Together these results show that the features used in this experiment all significantly contributed, in roughly equal proportion, to the experience of distinctiveness.

The results of Experiment 1A support that manipulating the number of different features can be used appropriately to assess distinctiveness along a continuum. The linear nature of the relationship shows that perceived levels of distinctiveness for basic objects is well explained by the feature-matching model. Also, the regression analysis above shows that each of the features used in the experiment contribute to the experience of distinctiveness (as evidenced that they are all individual significant predictors) and that there are limited issues with unequal levels of salience for the features chosen (as evidenced by their roughly-equal standardized β coefficients). Given that perceived distinctiveness is well-explained by the feature matching model further analyses in Experiment 1 will use raw number of different features as the operationalized measure of feature-level distinctiveness.

EXPERIMENT 1B: FEATURE-BASED DISTINCTIVENESS, MEMORY, & DURATION PERCEPTION

Experiment 1B was designed to observe distinctiveness' effect on memory and duration perception through a feature-based manipulation. The paradigm investigated distinctiveness' effects on memory, and duration perception simultaneously. In addition to observing the individual relationships this experiment assessed whether memory and duration perception are similarly responsive to manipulations of stimulus distinctiveness.

Method

Experimental Trials.

The stimuli used in Experiment 1B were the same as those used in Experiment 1A. Trials consisted of trains of ten, sequentially presented stimuli; of the ten stimuli, five had identical features, four differed by one feature, and one was a distinctive stimulus (from here forward these will be referred to as standards, one-offs, and distinctive respectively). The distinctive stimulus was manipulated to differ by three, five, or seven features from the standard stimuli within a trial and was placed in either the 5th or 8th position. Stimuli were positioned so that a standard always preceded the distinctive item. See Figure 3 below for an example set of trial stimuli. The stimuli in Figure 3 are labeled with a number representing the position they would appear in the train; in this example stimuli in positions 2, 4, 6, 7, and 10 are identical (standards), stimuli in positions 1, 3, 8, and 9 differ by one feature from the standards (one-offs), and the stimulus in position 5 is the distinctive stimulus (and differs by five features [size, shape, outline size, outline pattern, & gradient], from the standards in this example, i.e., 5-diff).

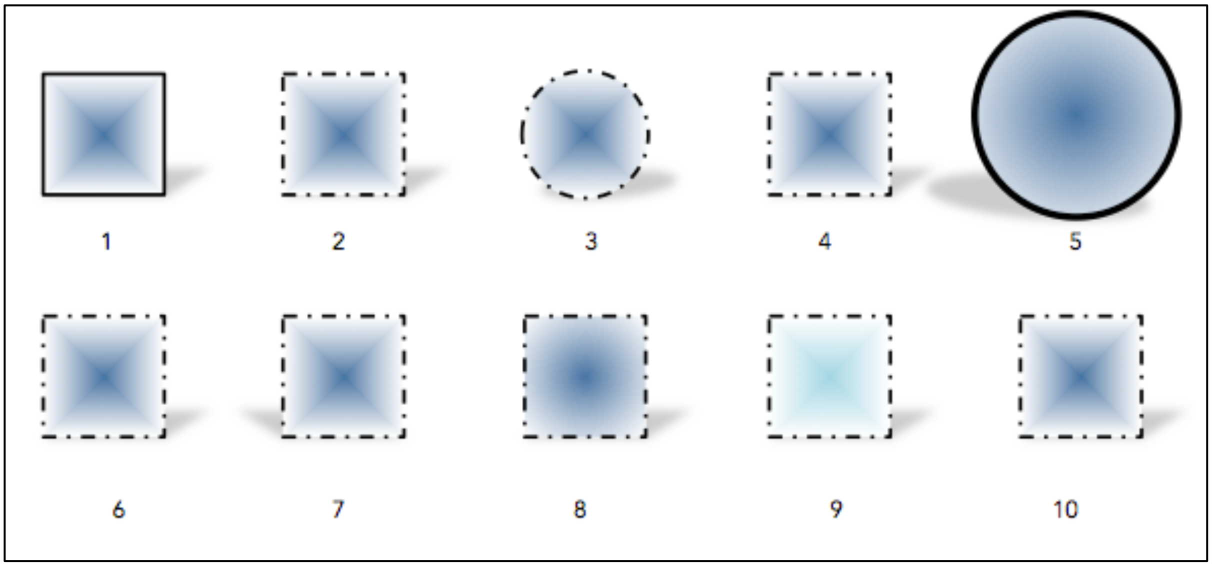


Figure 3. Example trial stimuli.

Stimuli were displayed after an interstimulus interval (ISI) consisting of a blank screen lasting between 750 and 1050 *ms*. The duration within a given trial was constant for all ten stimuli, however stimulus duration was manipulated between trials and had three levels: 150, 500, and 1050 *ms*. These durations were chosen to observe subjective time dilation over a range of values, where 150 milliseconds has been shown to be on the low end of a range that will elicit subjective temporal expansion, and further effects of expansion seem to be fairly asymptotic after 1000 milliseconds (Tse et al, 2004). Thus, the distinctive stimuli in the experiment had a 3 (distinctiveness level: 3, 5, or 7 different features) x 2 (distinctive stimulus position: 5^{th} or 8^{th} place in the sequence) x 3 (duration: 150, 500, or 1050 *ms*) experimental design.

After each stimulus, participants gave a duration estimate indicating how long they perceived the stimulus to be on the screen using a subjective, slider scale. Participants were instructed to make use of the full scale in their responses, and keep their use of the scale values proportional specifically to the stimuli within each trial.

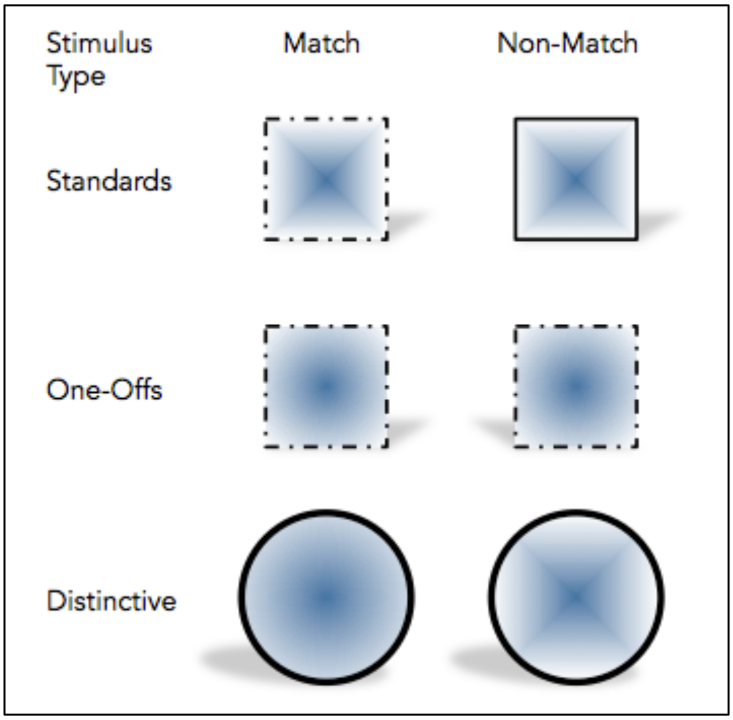


Figure 4. Example recognition probes.

Recognition Probes

Following one-half of trials there was a brief recognition probe where participants were given a stimulus and asked if they saw it in the preceding trial. The recognition probe stimuli were manipulated so that they either matched or appeared to be very similar to a stimulus seen in the trial (e.g., differed by one feature); for a pictorial example see Figure 4 above. The recognition probe stimuli were balanced so that there were equal numbers of target (or matching) and non-target (or non-matching stimuli), as well as equal numbers that mimic the identical, one-off, and distinctive stimuli. Participants had to indicate whether they saw the probe stimulus in the previous trial, and how confident they were in their judgment (on a scale from 0-100). The probe stimulus was not duration-limited, and participants were not required to answer within a certain time limit.

Working Memory Assessment.

Visual working memory, the ability to simultaneously store, process, and manipulate information (see Baddeley & Hitch 1974; Baddeley, 2003; Engle, 2002), will likely impact performance on the memory probes and the overall effect of distinctiveness as it relates to attentional control (Engle & Kane, 2004). A working memory assessment was administered at the beginning of the experiment. The working memory test used was an N-back test (see Kane & Engle, 2002; Kirchner, 1958; Mackworth, 1958; Owen et al., 2005) that presents a series of pictorial images to the subject. The subject's task is to indicate when the on-screen image matches what came 'n' before it in the series. The version used in this experiment was a 3-back test, meaning that subjects must remember the last three images they saw in the series, and indicate (through a mouse click) whenever the current, on-screen stimulus matches the 3-back stimulus [stored in memory]. Scoring was based on a composite of identification performance of 3-back stimuli (i.e., accuracy) and reaction times.

Procedure Overview.

All participants were run individually, in a research lab. Once giving informed consent and responding to demographic questions participants were administered the working memory assessment. Following the N-back test participants were first given practice trials for the experiment. During the practice session subjects saw examples of the experimental tasks in PsychoPy (Pierce, 2007) (e.g., giving duration estimates, and responding to recognition probes), and were familiarized with the use of the slider scale for duration estimates. Once subjects had practice and understood the instructions, the experiment would begin; 108 trials were presented randomly, with optional breaks after the 36th and 72nd trial. Following the conclusion of experimental trials subjects were debriefed about the nature of the experiment and assigned credit. Figure 5 below provides a visual representation of this procedure, and the flow for experimental trials.

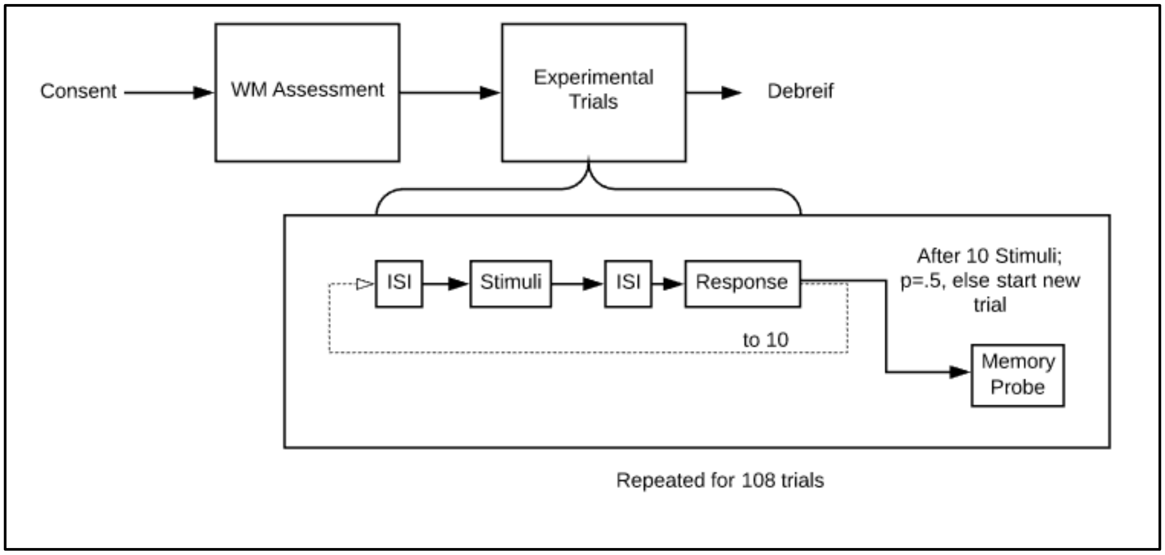


Figure 5. Flow Diagram of Experiment 1B Procedure.

Participants & Recruitment.

Participants were recruited from introductory psychology courses at North Carolina State University using SONA's online scheduling system, and compensated with experimental credit for the course. All subjects were required to be at least 18 years of age, understand English well enough to give informed consent, and have normal or corrected-to-normal vision to participate in the experiment. The obtained sample contained 77 participants; their mean age was 19.63 (*SD*= 2.60, Min= 18, Max= 35), and was made up of 55% males and 44% females.

Results and Discussion

Analyses for Experiment 1B focused on the perceived duration ratings and recognition probe responses. Rather than using raw values, Z-scores were calculated for the perceived duration ratings in a given trial—the rationale for this was that it gave a better measure of the *relative* dilation or contraction of perceived duration than raw ratings. To illustrate how this decision is beneficial consider the extreme case where two participants, on the same given trial of five stimuli gave the ratings [1, 1, 1, 1, 2] and [25, 25, 25, 25, 50]. Due to idiosyncratic scale use the raw average rating for each of stimuli would not be representative of either participant, even though the two participants relative dilation to the stimulus was equal (and has the same z-score). The responses to memory probes were coded as correct or incorrect, and their confidence was kept as a raw rating from 0-100, with higher values indicating a higher level of confidence.

Position Effects on Perceived Duration

The first analysis for Experiment 1B served as a manipulation check. Previous time perception research (using the same general "train" paradigm as this experiment) has consistently shown that perceived duration decreases over sequential presentations of stimuli (Kanai & Watanabe, 2006; Pariyadath & Eagleman, 2007; Rose & Summers, 1995; Tse et al., 2004; Van Wassenhove et al., 2008). The data in Experiment 1B show this same general trend (the main effect of train position on perceived duration was significant; $F(9, 675) = 9.79$, $p < .001$). Figure 6 displays this trend, in which earlier positions had higher time ratings, and later positions tended to receive lower perceived duration ratings. Although this result does not shed any light on the proposed hypotheses, it does show that the data obtained are consistent with previous research.

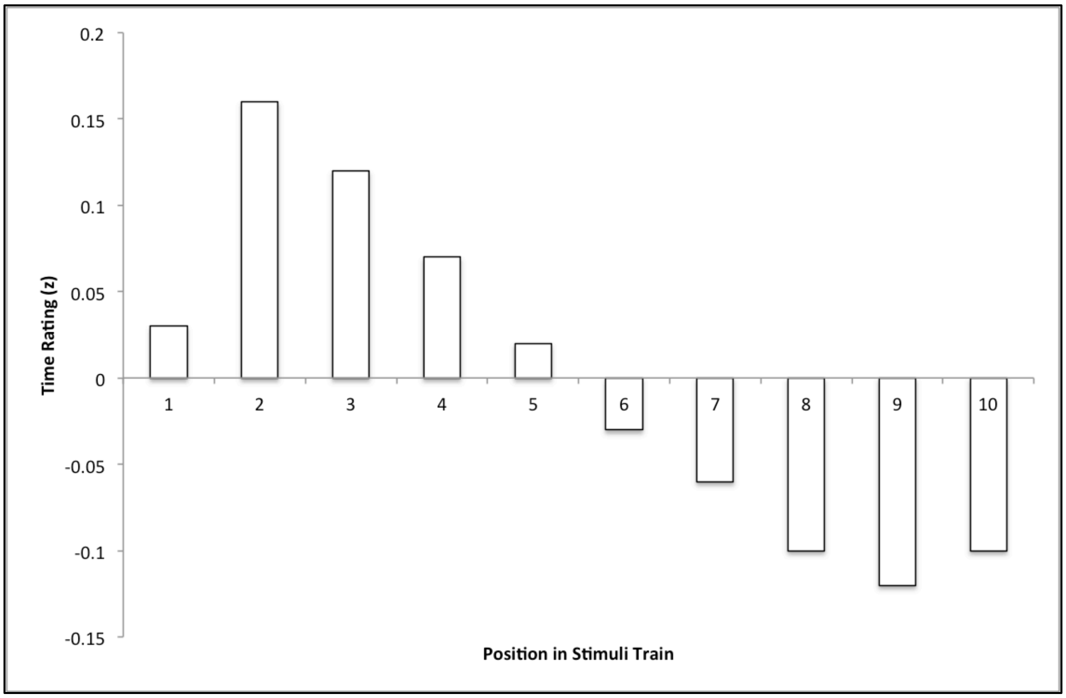


Figure 6. Time rating (z) by stimulus position.

Recognition Memory

The mean recognition accuracy by the distinctiveness level of the recognition probe can be seen in Figures 7 and 8 below. Generally speaking the recognition numbers are not very high, which indicates that participants likely had some difficulty with the task; this was reflected in relatively low confidence ratings (M=62.90, SD=26.22). Correct recognition of the probe was significantly greater than chance for standards (Z= 12.01, p< .001), one-off stimuli (Z= 3.93, p< .001), and three-diff stimuli (Z= 4.15, p< .001), however stimuli at the three and five different levels had recognition rates not significantly different than chance (Zs= 1.50 and 1.12, ps= .133 and .262 respectively)

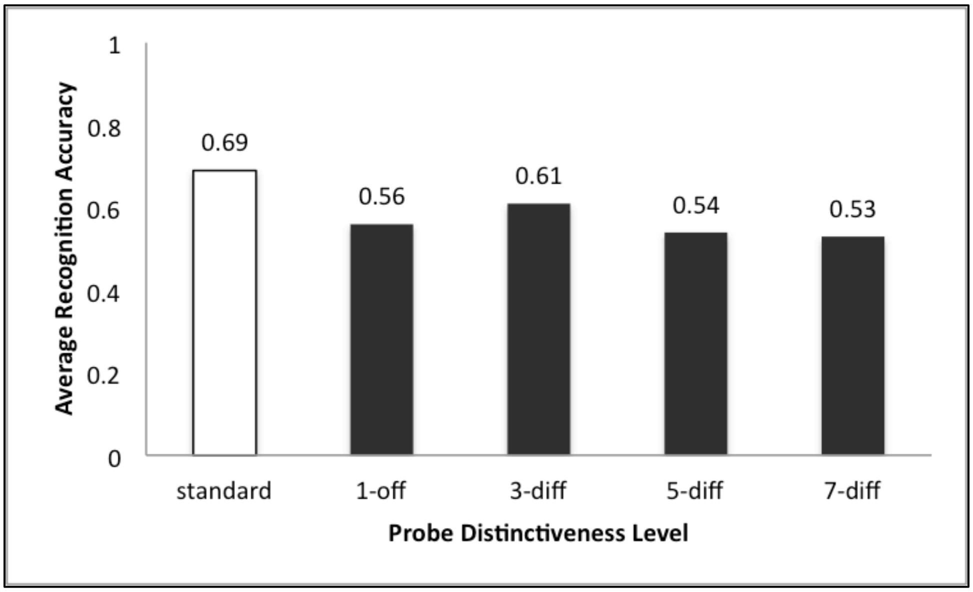


Figure 7. *Recognition accuracy by distinctiveness level of probe stimuli.*

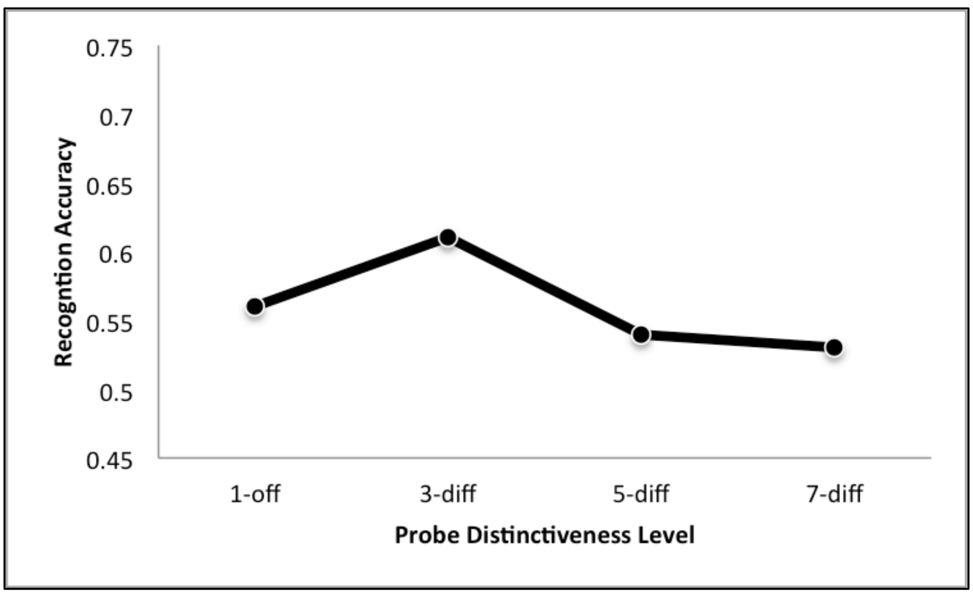


Figure 8 Relation between distinctiveness level and recognition accuracy, without standards.

One may note that the recognition accuracy was highest for probe stimuli that matched the standards of a given trial (*M*= 69%), however this average should not be directly compared to the other levels. As explained in the method, standards in a given trial were presented multiple times, but other stimuli types were only presented once (see Figure 3). For this reason the standards were filtered out of subsequent significance testing of the memory data (leaving only the levels reflected in Figure 8)

The effects of distinctiveness, stimulus duration, confidence rating, and working memory on recognition accuracy were assessed using a logistic regression; the overall model was significant ($X^2(4) = 42.12$, $p < .001$). Neither working memory score (Exp(β)= 1.00, Wald= 1.18, $p = .951$) nor confidence (Exp(β)= 1.01, Wald= 3.74, $p = .053$) had a significant impact on recognition accuracy. As expected, longer stimulus durations during the trial produced significantly higher (Exp(β)= 2.75, Wald= 30.47, $p < .001$) recognition rates on subsequent recognition probes—in other words with longer durations a participant had higher odds of encoding and later remembering the stimulus. The distinctiveness level of probe stimuli had a significant, but negative (Exp(β)= .91, Wald= 5.02, $p = .025$) impact on recognition accuracy; as distinctiveness increased probe stimuli were more difficult to remember. This finding conflicts with the experimenters predictions that increased levels of distinctiveness should *increase* the odds of accurately remembering the stimuli.

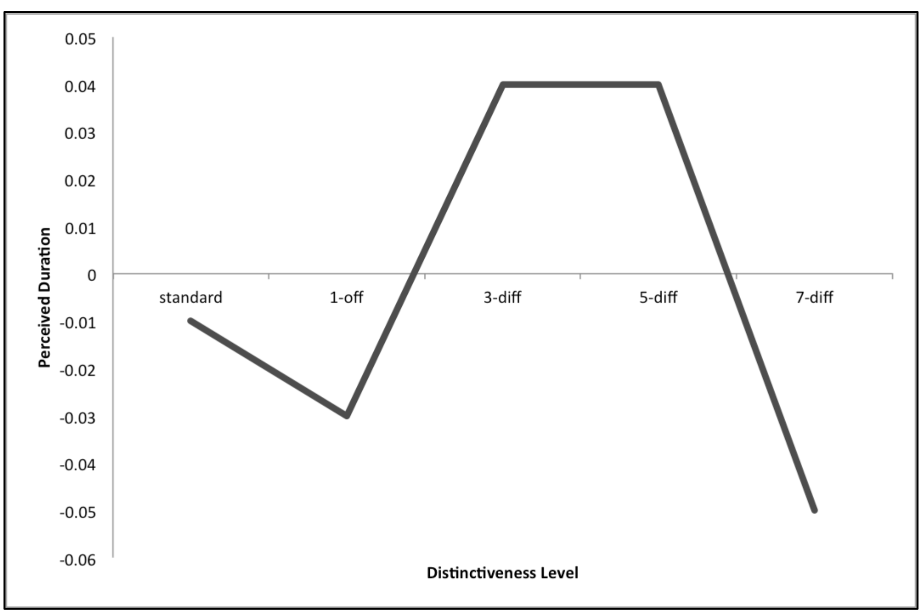


Figure 9. Perceived duration as a function of feature distinctiveness.

Duration

The general trend of distinctiveness on time perception was non-linear (see Figure 9 above); one can see that distinctive stimuli that differed by three or five different features had higher perceived durations than the standards and one-off stimuli, however the distinctive stimuli that differed by 7 features had the lowest overall perceived durations. Using an ANOVA, the effects of stimulus distinctiveness and stimulus duration on perceived duration (z-scores) were assessed. Neither of the main effects in the model were significant (Duration, $F(2, 150)= 1.93$, $p= .149$; Distinctiveness, $F(4, 300)= 1.07$, $p= .371$), but there was a significant distinctiveness*duration interaction ($F(8, 597)= 5.81$, $p< .001$); this interaction is visualized below in Figure 10. It was predicted that with longer presentation time (higher duration) more attention could be paid to the stimuli and the effect of distinctiveness on perceived time would increase, leading to a significant interaction. One can see that the relative time ratings for standard and one-off stimuli (dashed lines) held fairly constant across duration, and the relative dilation of the low level distinctive stimuli (3-different) increased with stimulus duration, but the two higher levels of distinctive stimuli (5 and 7 different) saw an effect where they were their time ratings contracted relative to standards as duration increased. This analysis, and the general means (displayed in Figure 9) ran counter to expectation. Much like the memory data previously analyzed it was seen that, for the three levels of distinctive stimuli used, higher distinctiveness levels (i.e., 5 and 7-different features) saw reduced perceived duration.

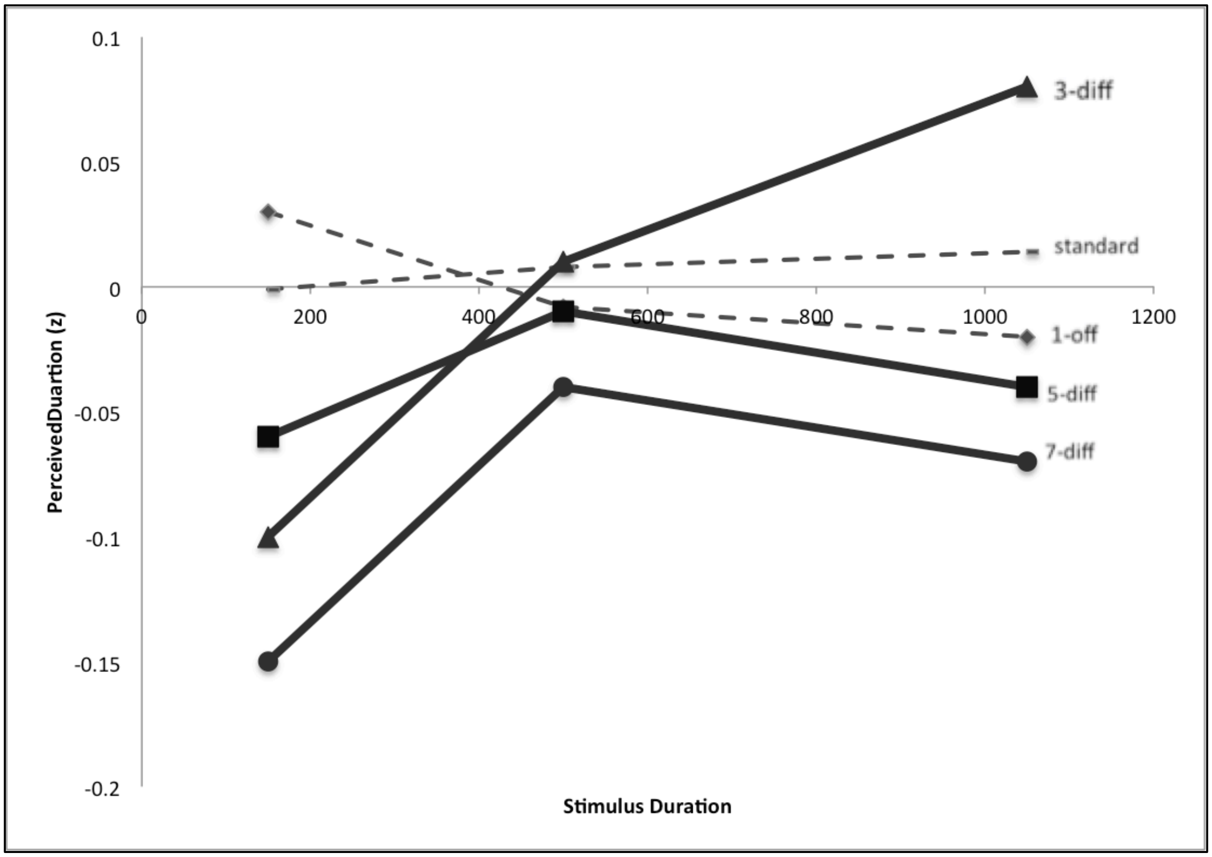


Figure 10. Distinctiveness and stimulus duration interaction plot.

Subject-Level Analyses

Interestingly both the memory and time perception data revealed a nonlinear trend, where both increased with distinctiveness up to a maximum level (around 3-different features), then decreasing with increased distinctiveness level. To investigate whether this quadratic trend held true for most participants a series of analyses was run at the subject-by-subject level. Each participant's perceived duration by distinctiveness, and recognition accuracy by distinctiveness, functions were analyzed using a hierarchical regression. The individual contribution (in terms of R^2) for distinctiveness (a linear predictor) and distinctiveness squared (a quadratic predictor) was assessed. A sign test revealed that most participants' relationship between perceived duration and distinctiveness was significantly better explained by a quadratic function (47 out of 74; Z= -1.98, p= .048), however this difference did not reach significance for the distinctiveness by memory relationship (43 out of 74; Z= -1.79, p= .073). This analysis informs us that the general two-phase trend found for the perceived duration data explains most participants' experience with distinctiveness.

Next, a series of two analyses was performed to analyze the similarity of each participant's time perception-distinctiveness and memory-distinctiveness relations. First the better-fit function (either linear or quadratic) of each participant was compared to see if they generally matched each other (i.e., the analysis looked at whether a person with a quadratic memory function was also likely to have a quadratic time perception function). The Phi-test (a measure of degree of association between two binary variables) revealed that there was not a significant association between the shape of a subjects time-distinctiveness and memory-distinctiveness relationship (Φ= -.16, p= .176). This analysis suggests that there is no relationship between the shape of a subjects memory-distinctiveness and time-distinctiveness functions (i.e., having a quadratic function for one does not mean the other would be more likely to be quadratic as well). Second, the β weights for the time and memory functions were correlated; neither the linear (r= .10, p= .403) or quadratic (r= .10, p=. 412) predictor's β were significantly correlated. These analyses indicate that that even though the overall sample trends for distinctiveness' effect on memory and time perception are similar, and most individuals show a quadratic relationship there is little evidence that the two are related to each other. So, whereas time perception and memory seem to be similarly responsive to manipulated distinctiveness (evidenced by their similar trends at both the sample level), it does not appear that the two have a large overlap in processing (as there seems to be no relationship between the two at a subject-level).

Feature Distinctiveness, Working Memory Load, & Discussion

The analyses so far show convincing results that the relationship between feature-based distinctiveness, and memory and time perception is not linear. Rather it seems that memory increases and perceived duration dilates with distinctiveness up to a point, where after the relationship becomes negative for more distinctive items. This concurrence between the whole-sample memory, duration perception results and the findings of the individual functions gives good evidence that the two relationships explored are not monotonic as proposed, and that they are better explained by a two-phase function. One key to understanding this result may lie in the experimental paradigm being set up as a dual task, in which both memory and duration-related information had to be processed within a trial. Previous research on tasks in which temporal and non-temporal information must be attended shows that, when attentional processing is captured by non-temporal information, people have less remaining capacity for attention to temporal information—when this decreased attention to temporal information happens perceived duration decreases (Brown, 1985; Kahneman, 1973). Accordingly, for the lower levels of distinctiveness there was sufficient capacity for participants to process both time-related information and also memorize the stimuli for later recognition on memory probes. However, once stimuli became too distinct, more effort and capacity had to be devoted towards processing the different features of the distinctive stimulus which left less processing capacity for the duration related information, which consequently reduced perceived duration. In the absence of a dual task, this two-phase function would likely not occur – both memory and perceived time would likely increase across the entire range of distinctiveness. However, due to the load on attention and working memory for the highly distinct stimuli take too much effort to process, which in turn results in a contraction of perceived duration.

One final analysis was aimed at testing this two-phase theory: using an ANOVA the effect of the distinctive event on perceived duration was assessed as it related to high and low working memory scores. Working memory score (median split; high, low), level of distinctiveness, and a third variable of position (filtered to two values: the distinctive item and the preceding standard) were used as predictors. There was a significant three-way interaction between position, distinctiveness level, and working memory ($F(4, 12028)= 3.52$, $p= .030$), which indicates that the effect of the distinctive stimuli and distinctiveness level of that stimulus was different based on whether someone had high or low working memory. The key difference in this interaction was between high working memory (Figure 11a) and low working memory (Figure 11b) individuals. Note that, for low working memory individuals, all levels of distinctiveness lead to a contraction of perceived duration (i.e., for people with low working memory all values of feature distinctiveness imposed a working memory load that took away from temporal processing). On the other hand, high working memory individuals perceived duration increased for the low (3-different) and medium (5-different) levels of distinctiveness. High working memory individuals only see contracted time ratings for the highest level of distinctiveness (7-different). The finding that high working memory individuals are less prone to contractions for lower levels of distinctiveness supports the theory that high distinctiveness presents a working memory load that causes more attention to be paid to non-time relevant information, producing the downward second-phase of the relationship found in this experiment.

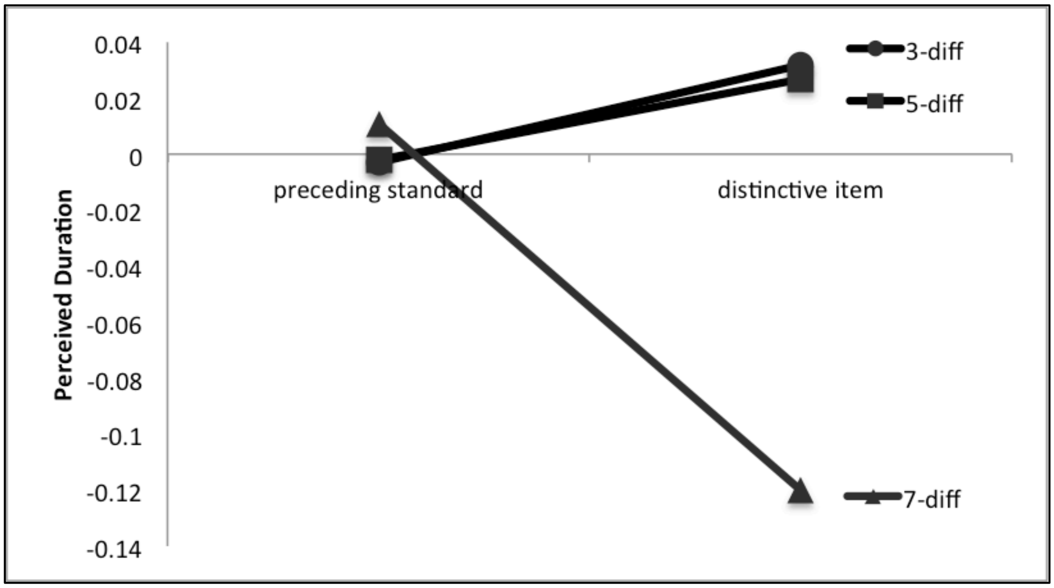


Figure 11a. *High working memory: Position*feature distinctiveness level interaction.*

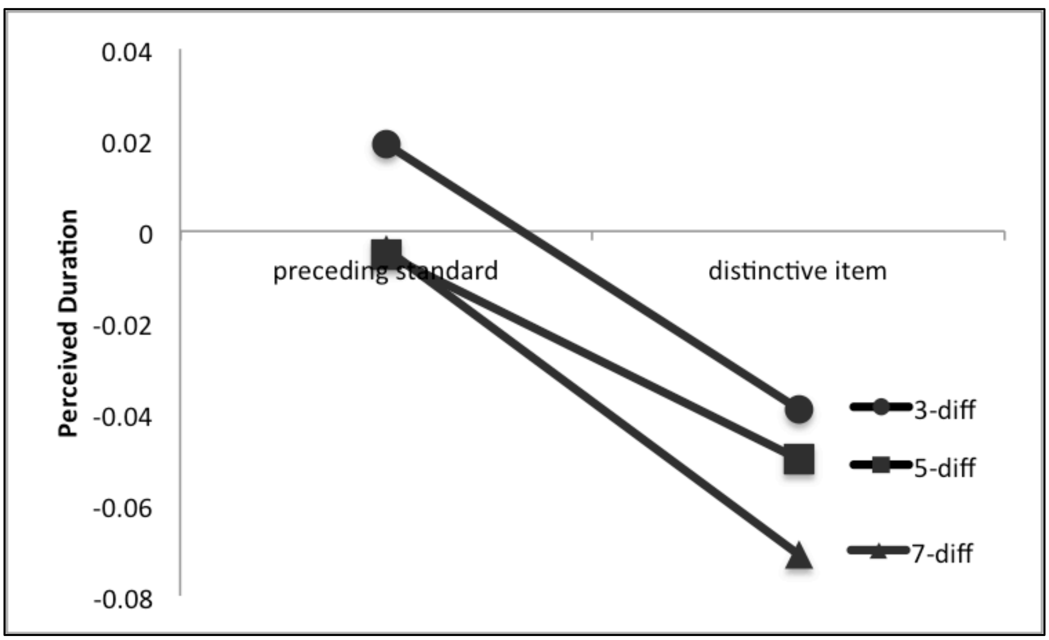


Figure 11b. *Low working memory: Position*feature distinctiveness level interaction.*

In summary Experiment 1B had four key findings:

(1) Contrary to predictions feature distinctiveness' effects on time perception and memory were not linear in nature.

(2) Time perception and memory were found to be similarly responsive to manipulations in feature distinctiveness, and both roughly matched a two-phase ("inverted-U") function.

Initial increases in distinctiveness elicit increases in memory and perceived duration. However this reaches a maximum point and actually reverses trend for high values of feature distinctiveness.

(3) There was no significant association between a subject's time and memory relationship with distinctiveness.

(4) The cause of the two-phase relationship for feature distinctiveness seems to rest on a working memory load presented by highly distinctive items.

EXPERIMENT 2A: SUBJECTIVE RATINGS FOR CATEGORICALLY DISTINCT STIMULI

Method

Experimental Stimuli

Experiment 2A was designed to mirror the general design of Experiment 1A, however the type of stimuli used were different. Whereas Experiment 1A manipulated the feature distinctiveness of stimuli, Experiment 2A focused on distinctiveness of real world stimuli. In total there were 12 categories used; dogs, cats, fish, large-horned mammals (i.e., deer), vegetables, fruits, trees, flowers, rocks, computers, office supplies, and cars. These categories were chosen as stimuli that are familiar to most people so that a coherent knowledge structure could be obtained using subjects from the general population (i.e., categories of things that do not take expert knowledge to organize).

Subjective Ratings

During the course of Experiment 2A participants saw pairs of stimuli sampled from the set of 12 categories. For each pair that was presented, one stimulus would be given as the comparator and the other as the referent (e.g., "How similar is [image of dog] to [image of cat]"). In total, there were 144 different combinations of comparisons; 132 combinations containing pairs of different categories as the referent/comparator, and 12 that had same-category pairs. Each subject saw two trials for each combination of comparison, making for 288 total comparisons during the experiment.

Participants & Recruitment

Participants for Experiment 2A were recruited through Amazon's Mechanical Turk and were compensated $1.50 for participating. All participants were required to be at least 18 years of age, have a lifetime task approval rating of at least 95%, have normal or corrected-to-normal vision, and speak English with enough proficiency to understand the language of the consent form and understand instructions given during the experiment. Ninety-five subjects volunteered for the experiment. Demographics for the sample are given in Table 3 below.

Results

Whereas Experiment 1A was primarily concerned with analyzing the relationship between distinctiveness (as manipulated through features) and perceived distinctiveness, Experiment 2A's primary aim was to find the degree to which the categories used were perceived as being distinct from each other so that they may be placed into a continuum. Put simply, the point of Experiment 2A was to get ratings of the proposed categories so that a sampling of comparisons could be used for the different levels of distinctiveness in Experiment 2B.

Table 3. Sample Demographics for Experiment 2A

Gender	Frequency	Percent of total responses
Male	25	(38.5%)
Female	39	(60%)
Other	1	(1.5%)
Age		
18-25	5	(7.7%)
26-35	35	(53.8%)
36-45	12	(18.5%)
46-55	8	(12.3%)
56+	5	(7.7%)
Education Level		
High school	11	(16.9%)
Some college	14	(21.5%)
2-year degree	9	(13.8%)
4-year degree	26	(40%)
Graduate degree	5	(7.7%)

Note: Some participants opted out of answering demographic questions. Percentages are given out of total responses received.

Generally speaking, distinctiveness ratings for most of the comparisons between categories were high (see the boxplot in Figure 12). Fortunately, there were enough observations in the main box, and long tail to take a sampling of stimulus category pairs for Experiment 2B. In Experiment 1B the three levels of distinctiveness used had average subjective ratings of 5.3, 7.43 and 8.98. Using these numbers as a guide pairs from Experiment 2A were sampled for use in the three levels of distinctiveness in Experiment 2B; this was done to ensure that the distinctiveness levels in Experiment 1B and 2B were roughly equivalent in their level of perceived distinctiveness.

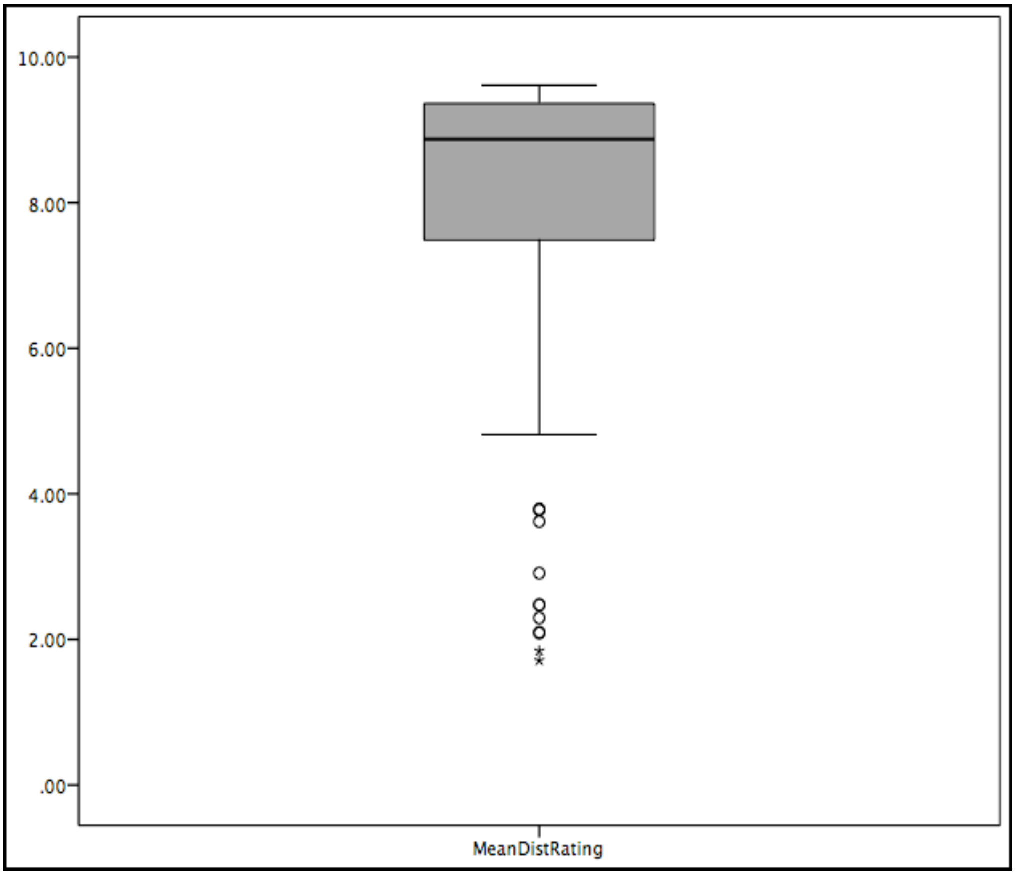


Figure 12. *Boxplot of mean distinctiveness ratings*.

In addition to the descriptive analysis above, a pathfinder network was obtained for the distinctiveness ratings (for general information on pathfinder networks see Schvaneveldt, 1990). There were two purposes for obtaining pathfinder networks: (1) to further validate the use of the distinctiveness ratings through coherence data, and (2) to analyze how the raw ratings obtained in Experiment 2A relate to the strength of association between the concepts in the knowledge structure.

Using jPath (Interlink Inc., 2018) the network was obtained using standard parameters (q=n-1, r=inf); summary information for the pathfinder network can be found in Appendix A. Coherence is a metric of the internal consistency of a pathfinder network, in which numbers closer to 1 indicate high consistency, and numbers below .15 are regarded as extremely low (which indicates there may be a flaw in data or that participants did not understand the concepts and their relations well). The obtained network had a Coherence value of C=.81, which is consistent with "expert" levels of coherence in other pathfinder studies (Rowe, Schvaneveldt, & Bennett, 2007). This result demonstrates that the sample had adequate knowledge to construct a representative and consistent, structural representation of the similarity and dissimilarity of the categories.

Next, the link weights (a measure of similarity of the items in the pathfinder network) were compared to the distinctiveness ratings in the rating study. What this analysis tells us is how well the distinctiveness rating corresponds to the degree of similarity (or connectedness) of the two categories in the output knowledge representation network. Theoretically, if the data are consistent, this value should be high. A Pearson correlation revealed that there was a strong, negative relationship between distinctiveness rating and link weight in the pathfinder network(r= -.99, $p<.001$). In other words there was a strong inverse relationship between the subjective ratings of how distinct the pairs were and the degree of relatedness in the pathfinder network obtained. Taken together this result and the level of coherence in the obtained network show that the subjective ratings obtained in Experiment 2A are highly consistent, and describe a well-formed mental representation of distinctiveness for the stimuli categories chosen, validating their use in Experiment 2B.

EXPERIMENT 2B: CATEGORICAL DISTINCTIVENESS, MEMORY, & TIME PERCEPTION

Method

Experimental Trials.

The paradigm and general procedure of Experiment 2B were designed to be similar to Experiment 1B, with the exception of the use of categorically distinct, real world stimuli. Each trial sequentially presented 10 images; 9 were from a “standard” category, with 1 image from a different category acting as the distinctive stimulus. There were three levels of distinctive stimuli (low, medium, high) that were sampled from various ranges of the distinctiveness ratings (and pathfinder link weights) from Experiment 2A. These ranges were chosen to roughly match the degree of difference (from standards, in terms of distinctiveness rating) for the 3-off, 5-off and 7-off stimuli in Experiments 1A and 1B (see Experiment 2A above for details).

Each stimulus in a given trial was displayed after an ISI (consisting of a blank screen) lasting between 750 and 1050 *ms*; this ISI also appeared between the stimulus and the time rating (see Figure 13 below). The same subjective, slider scale used in Experiment 1B was used for Experiment 2B. Within a given trial all stimuli were displayed for the same duration, however between trials duration was manipulated and had three levels: 150, 500, and 1050 *ms*. In each trial the distinctive stimulus always occurred in either the 5th or 8th serial position, with standards filling all other positions. In summary, the distinctive stimulus within a trial varied by duration (three levels: 150, 500, 1050 *ms*), the degree of distinctiveness to the standards (three levels: low, medium, high), and the onset of the distinctive stimulus in the series (two levels: 5th or 8th serial position).

Recognition Tests.

Following one-half of trials there, participants received a brief recognition test in which they were presented with a stimulus and asked if they had seen it in the preceding trial. The recognition probe stimuli were balanced so that there were equal numbers of target (or matching) and non-target (or non-matching stimuli), as well as equal numbers that mimicked the standard and distinctive stimuli, and equal numbers from trials of the three levels of stimulus duration. In addition to asking participants to indicate whether they saw the probe stimulus in the preceding trial, they were also asked to indicate how confident they were in their judgment on a scale from 0-100.

Working Memory Assessment.

The working memory assessment used in Experiment 2B was identical to that used in Experiment 1B—an n-back test aimed at testing visual working memory.

Procedure Overview.

Participants for Experiment 2B were run individually, in a research laboratory at North Carolina State University. After giving informed consent and responding to demographic questions participants were administered the working memory assessment. Following the N-back test participants were first given instructions and practice trials for the experiment. During practice, participants saw examples of the experimental trials and were given the opportunity to ask questions about the tasks involved in the experiment (e.g., giving duration estimates using the slider scale and responding to recognition probes). After practice, subjects began the experiment, in which 108 trials were presented randomly, with optional breaks after the 36th and 72nd trial. Following the conclusion of experimental trials subjects were debriefed about the nature of the experiment and assigned credit.

Participants & Recruitment

Participants were recruited from introductory psychology courses at North Carolina State University using the online scheduling system, SONA, and compensated with experimental credit for the course. All subjects were required to be at least 18 years of age, understand English well enough to give informed consent, and have normal or corrected-to-normal vision to participate in the experiment. The obtained sample contained 61 participants, with a mean age of 19.96 (SD= 2.42, Min= 18, Max= 36), and was comprised of 33% males and 66% females.

Results and Discussion

The analyses for Experiment 2B were very similar to those for Experiment 1B and focused on perceived duration ratings and recognition probe responses. Again, the time ratings were adjusted to z-scores so that the effects of time dilation and contraction on a given trial would be relative, and the effects of individual differences in scale use eliminated. Responses to recognition probes were coded as incorrect or correct, with their associated confidence judgments kept as raw ratings from 0-100 (with higher values indicating more confidence in correct identification/rejection of a memory probe).

The initial analysis for Experiment 2B was analyzing the effect of position in the stimuli train on perceived duration. Recall that previous research (and the results from Experiment 1B) finds a consistent trend where subjective duration decreases over multiple presentations of stimuli. Again, this effect was present (as one can see in Figure 13 below) and significant ($F(9, 549)= 11.22, p< .001$). Although this result does not relate to the proposed hypotheses, it serves as a manipulation check in that it shows that the data obtained are similar to other experiments using the same paradigm.

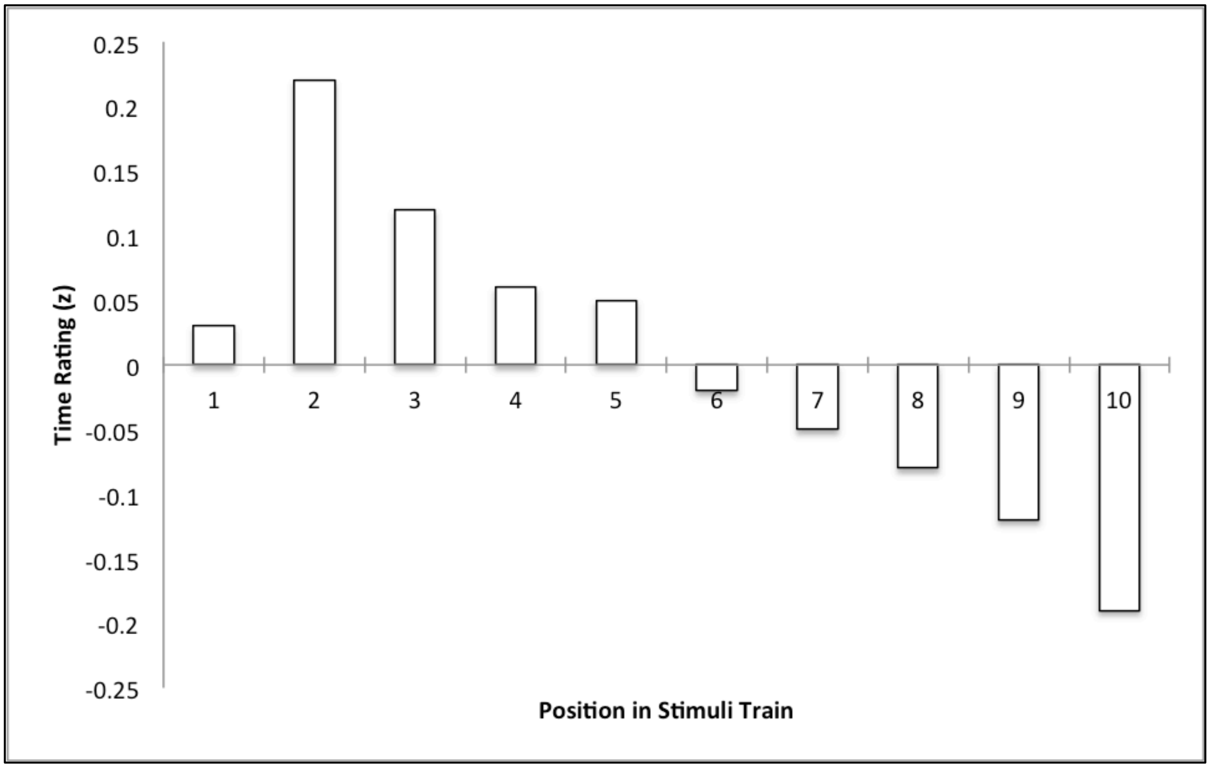


Figure 13. Perceived duration (z) by stimulus position.

Memory

Next the effects of distinctiveness on memory were investigated through a logistic regression; the predictor variables included were working memory composite score, distinctiveness level of the probe, duration of the trial stimuli, and confidence rating. The overall model was significant ($X^2(4)= 141.26$, $p< .001$), and probe distinctiveness level ($Exp(\beta)= 1.10$, Wald= 3.73, $p= .050$) and confidence ratings ($Exp(\beta)= 1.02$, Wald= 12.19, $p< .001$) were significant individual predictors. Each of the significant predictors had positive relationships with recognition accuracy, meaning that increased values of distinctiveness (visualized in Figure 14 below) and confidence both coincided with higher odds ratios of correctly identifying the probe; it is also worth noting that each distinctiveness level had recognition rates higher than chance (standards, $Z= 8.66$, $p< .001$; low distinctiveness $Z=$

14.76, $p < .001$; medium distinctiveness, $Z = 33.92$, $p < .001$; high distinctiveness, $Z = 36.82$, $p < .001$). However, duration ($Exp(\beta) = .93$, $Wald = .24$, $p = .624$) and working memory score ($Exp(\beta) = 1.00$, $Wald = .17$, $p = .673$) were not significant. It is interesting that neither working memory or stimulus duration had an effect on recognition accuracy, given that it would be a reasonable assumption that both (or either) of them could facilitate accurately remembering stimuli.

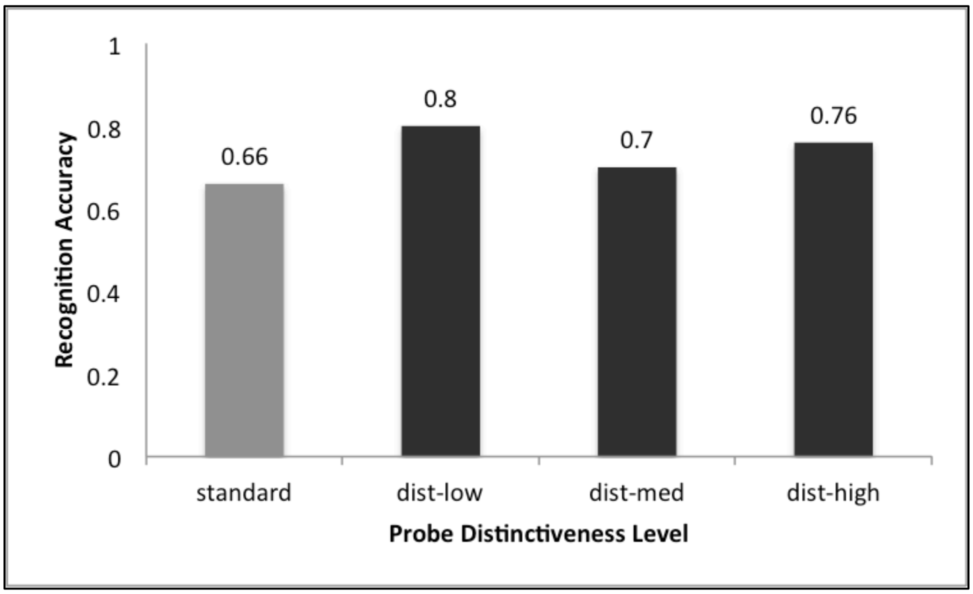


Figure 14. Recognition accuracy rates by probe distinctiveness level.

The results of this logistic regression for Experiment 1B and Experiment 2B were different in two important ways. First, stimulus duration was a significant predictor for recognition accuracy with feature distinct stimuli, but not for categorically distinct stimuli. In other words, how long stimuli were displayed during the trial did not affect recognition for categorical stimuli, but it did for feature-based stimuli. The categorical stimuli seem as though they are more efficiently processed than feature distinct stimuli, which benefit from longer presentation durations. The second major difference was that distinctiveness was a significant positive predictor of recall accuracy only for categorical stimuli. With feature distinct stimuli it was observed that there was actually a significant negative effect of distinctiveness on recognition once standard stimuli were filtered out, indicating that recognition was actually more difficult as distinctiveness increased. Also recognition rates are much higher for Experiment 2B than for 1B ($Z = 8.66$, $p < .001$) which is consistent with idea that the memory task required less cognitive effort with categorical stimuli.

Duration

The relationship between perceived duration and categorical distinctiveness also seems to differ from the pattern for feature-based distinctiveness; the overall means by categorical distinctiveness is visualized below in Figure 15. The figure shows that the perceived duration for standards is lower than the distinctive items, and the distinctive items show very little difference from one another. This is backed up by a simple one-way ANOVA where there is a significant main effect of distinctiveness, $F(3, 183) = 3.06$, $p < .001$; with Student-Newman-Keuls post-hoc tests revealing significant differences between standards and all distinctiveness levels ($p < .05$), but none of the distinctive conditions differing from each other (all $p > .05$).

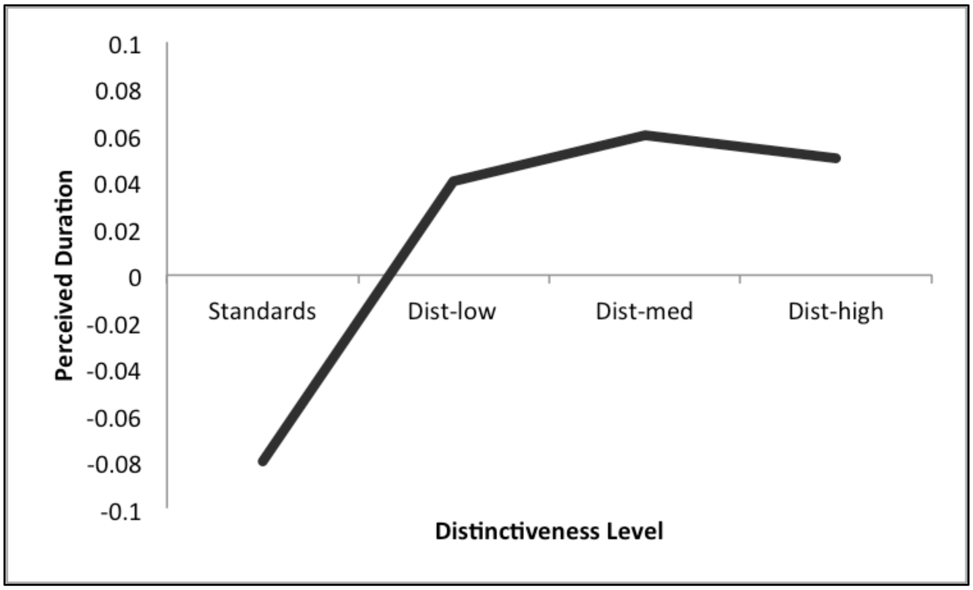


Figure 15. Perceived duration by distinctiveness level.

Further significance testing assessed the effect that stimulus duration had on the categorical distinctiveness-perceived duration relationship. Results showed a significant main effect of stimulus duration ($F(2, 122)= 4.66$, $p= .011$) and a significant distinctiveness*duration interaction ($F(6, 365)= 3.06$, $p= .006$), but the main effect of distinctiveness was not significant ($F(3, 183)= .25$, $p= .857$). The distinctiveness*duration interaction is visualized in Figure 16 below. This interaction fits well with the proposed hypotheses, as it shows that (for categorically distinct stimuli) with increased duration the dilation effect of distinctiveness on perceived duration increases.

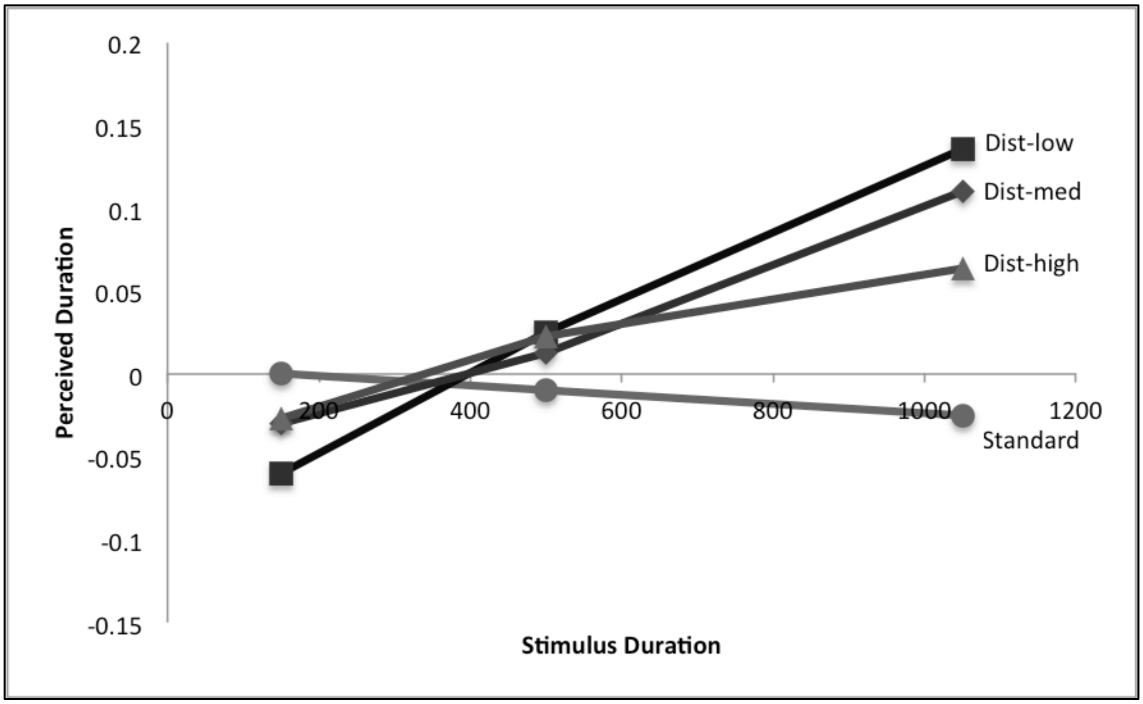


Figure 16. *Categorical distinctiveness, stimulus duration interaction.*

Subject-Level Analyses

Similar to the subject-level analyses conducted in Experiment 1B, the duration perception-distinctiveness and memory-distinctiveness functions for the participants in Experiment 2B were analyzed. Each participant's perceived duration by distinctiveness, and recognition accuracy by distinctiveness functions were analyzed using a hierarchical regression to compare the individual contribution (in terms of R^2) for distinctiveness and distinctiveness squared (i.e., a quadratic predictor). Comparing the R^2 for each participant using a sign test, neither the memory (Z= -1.14, p= .253) nor time perception (Z= -1.28, p= .200) relationship with categorical distinctiveness was significantly better explained by a linear or quadratic function. So, neither a quadratic or linear function did a better job explaining the memory/time perception-distinctiveness relationship for most participants. This result is not surprising given the shape of the data seen in Figures 14 and 15 (above), as they are both generally well described as asymptotic, with little difference between the varying levels of distinctive stimuli. Further, it was shown that there is no association between whether a subject's memory-distinctiveness and time-distinctiveness relationship was better described by linear or quadratic functions (Φ= .03, *p*= .792). Additionally there was were only low, nonsignificnat correlations between the β weights of the same shape functions (*rs*= .05 and .15, *ps*= .722 and .253 for correlations of the linear and quadratic components, respectively).

Categorical Distinctiveness, Working Memory Load, and Discussion

Unlike Experiment 1B, the results of Experiment 2B did not exhibit a two-phase function. Rather, they are better explained by an asymptotic function (distinctive ceiling effects) whereby any level of categorical distinctiveness resulted in higher perceived durations and recognition accuracy. How does one explain the difference between the findings for categorical and feature-based distinctiveness? One explanation focuses on the primary difference between the two cases: the categorically distinct stimuli fit into natural categories, which facilitates memory for them. Compared to the feature distinct stimuli in Experiment 1B (which have no natural or preexisting mental schema), the categorically distinct stimuli in Experiment 2B can be organized into natural categories, which likely made storing these stimuli for later memory probes easier. Backing this theory is the finding that the three-way interaction among position (distinctive stimulus vs. the preceding standard), working memory, and distinctiveness level interaction was significant in Experiment 1B but not in Experiment 2B ($F(2, 8822)$= .74, *p*= .476). In other words, low working memory (Figure 17b) and high working memory (Figure 17a) individuals both reported dilated duration perception for all levels of categorical distinctiveness. This indicates that increased categorical distinctiveness, due to easy facilitation of encoding, did not impose a higher working memory load for participants.

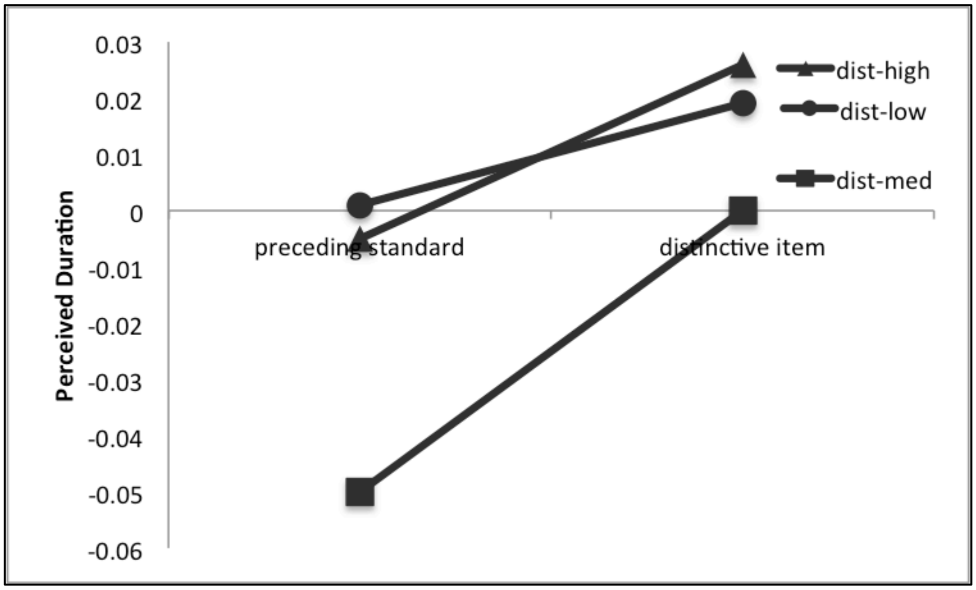


Figure 17a. *High working memory: position*distinctiveness interaction*.

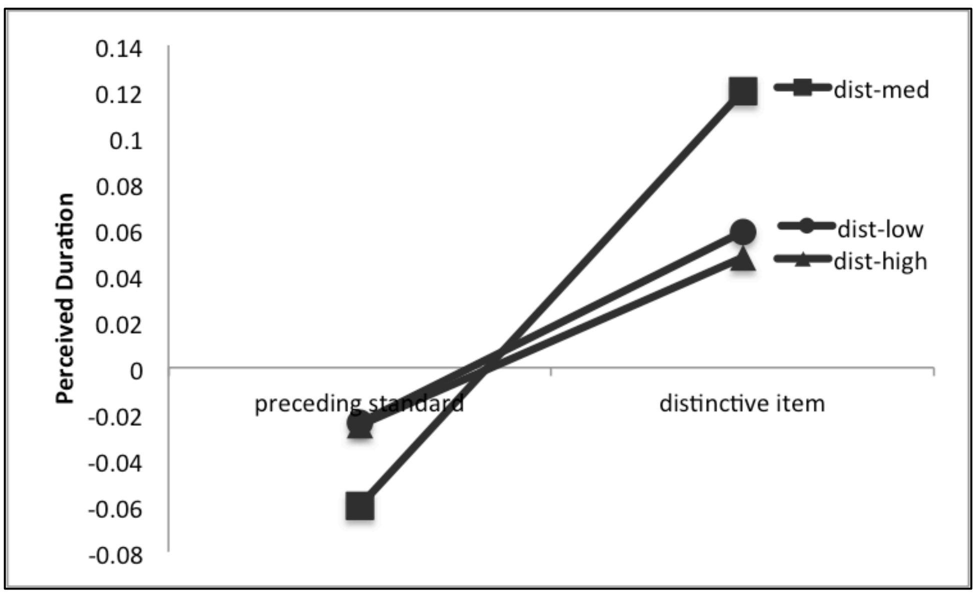


Figure 17b. *Low working memory: position*distinctiveness interaction*

In summary there were four key findings in Experiment 2B:

(1) Distinctiveness based on conceptual categories produced different effects from distinctiveness based on the features of the objects in a given set.

(2) Categorical distinctiveness' relationship with both memory and duration perception can be described as asymptotic, where any level of distinctiveness from standards results in higher perceived durations and higher odds of recognition accuracy.

(3) There was no significant association between a subject's time and memory relationship with distinctiveness.

(4) Correct recognition of categorically distinct stimuli was far easier than correct recognition of feature-distinct stimuli, and does not impose a working memory load.

GENERAL DISCUSSION

The experiments presented in this document provide methodological contributions to the study of distinctiveness and have important implications for the processing of distinctive stimuli in terms of both duration perception and memory. Although previous research has attempted to vary the degree of distinctiveness (Eriksen, 1963; Gumenik & Levitt, 1968; Kimble & Dufort, 1955) among the experimental stimuli, the present research presents a more empirical way of deriving these levels for both feature-based (Experiment 1A) and categorical (Experiment 2A) or conceptual distinctiveness than previous examples. Borrowing from literature on features, similarity, and dissimilarity and using a separate sample to give subjective ratings of the stimuli gave the experimenters an empirical basis for the degrees of distinctiveness used in Experiments 1B and 2B. This methodology provides the advantage of giving an empirical method to ensure that the measures of distinctiveness used were reliable, accurately represented the psychological experience of distinctiveness, and provided a continuum to assess both types of distinctiveness that affords observing the shape of a relationship.

By breaking down distinctiveness into two different forms, perceptual features and categorical/conceptual differences, researchers observed that these types of distinctiveness have a different pattern in terms of their effects on memory and time perception. In Experiment 1B it was seen that this relationship can be best explained by a two-phase model, whereby feature distinctiveness initially has a positive effect on memory and increases perceived duration. However, once items become more distinct, too much attention is taken up by the task of processing the features of the stimulus, which leaves less attention for duration-related information. In turn this decreased attention to time relevant cues leading to a contraction of perceived duration, creating the downward second phase of the relationship. However, an experiment in which participants only had to estimate durations might produce a different outcome – that is a prediction form the two-process account described above.

The effect of categorical distinctiveness did not fit a two-phase model, rather it could be better described as asymptotic. As observed in Experiment 2B, when an item was distinctive it both increased memory for that item and was observed to receive increased ratings of subjective duration. No matter the degree of categorical difference between the standard and distinctive item the effect was roughly the same. In other words, it appears that, for categories, any degree of distinctiveness above a fairly low criterion level, elicits the von Restorff and oddball effects, in contrast to feature distinctiveness where this is only true up to a maximum point, after which the effect reverses trend and subjective duration and memory for the item decreases. An important implication of these results is that both the von Restorff and oddball effects (as well as other various, less notable effects of subjective duration) are not as simple as they are often presented in the literature; task scenario and context can change the trends of these effects as was the case with feature based distinctiveness where it was found that once distinctiveness of the oddball/isolated item is increased enough the effects completely reverse.

A further implication of the difference between Experiments 1B and 2B is that the membership of a stimulus to an already existing category facilitates memory for it. Taking this one step further, it appears that ease of memory facilitation changes the relationship between distinctiveness and duration perception or memory. Having to attend to both temporal and non-temporal, task-relevant information imposed a working memory load for participants, and this working memory load increased with increased levels of feature distinctiveness in Experiment 1B, but not with categories in Experiment 2B. The various stimuli (and their combinations) in the feature experiment had no preconceived schema, whereas the stimuli in the categories experiment fit well into already existing knowledge structure and were easier to remember as a result (as evidenced by the coherence of the pathfinder network in Experiment 2A). However, the degree to which a well-structured mental schema is required to find asymptotic distinctiveness effects is unknown. It could be true that categorically distinct stimuli that are novel or domain-specific could see a similar pattern of results as Experiment 1B for novices. Investigating the effect of degree of knowledge structure on the ability to assign meaning to stimuli used in an isolation paradigm has potential opportunity for future work. For example, if a similar experiment were set up using engine parts and compared diesel mechanics to novices it could be found that the novices (in addition to having different relative distinctiveness ratings for given pairs of stimuli) would see distinctiveness effects more similar to those found for feature distinctiveness (like in Experiment 1B). On the other hand the mechanics might see distinctiveness effects more similar to those found for categorically distinct stimuli (like in

Experiment 2B) due to their ability to interpret the stimuli as members of meaningful categories that have relations to one another.

It is worth noting that the paradigm, as it was set up in this series of experiments, serves as a dual task for participants. Rather than simply giving estimates of duration, or having to observe stimuli for later recognition tests participants had to engage in both tasks during the same session. Future research could investigate whether having to engage in both tasks at once verses single task conditions changes the trend that distinctiveness has on memory and duration perception. It could be suggested that if a participant only had to do one task at a time the difference in trend between the feature (two-phase) and categorically (asymptotic) distinct stimuli may not be found. For example, say an experiment was set up using the same feature-based stimuli as in Experiments 1A and 1B with counterbalanced blocks where participants engage in one of the two experimental tasks (memory and duration judgments). The results of this experiment could very likely not match the two-phase trend for the feature distinct stimuli, instead the function may appear linear or asymptotic like what was seen for the categorically distinct stimuli in Experiment 2B. It is worth acknowledging that knowing how both these effects work in isolation is valuable, but it is very rare that a person engages in only time judgments or only recognition in a real world task.

Although distinctiveness' effect on memory and subjective duration still requires future investigation the set of experiments presented in this paper serve to advance the literature in a number of ways. In summary, these experiments contribute to the literature of distinctiveness by: (1) giving an example for an empirical method of deriving values of distinctiveness along a scale, (2) distinguishing between feature-based and categorical distinctiveness for visual stimuli, (3) establishing that distinctiveness' effect on memory and time perception act differently when other concurrent tasks demand attentional processing, (4) establishing that feature distinct stimuli impose a working memory load that results in a two-phase function whereby initial distinctiveness increases subjective duration and memory, but increased levels reverse the direction of the trend, and (5) establishing that categorically distinct stimuli, because of their natural knowledge organization, can facilitate memory and result in asymptotic distinctiveness effects for both memory and perceived duration.

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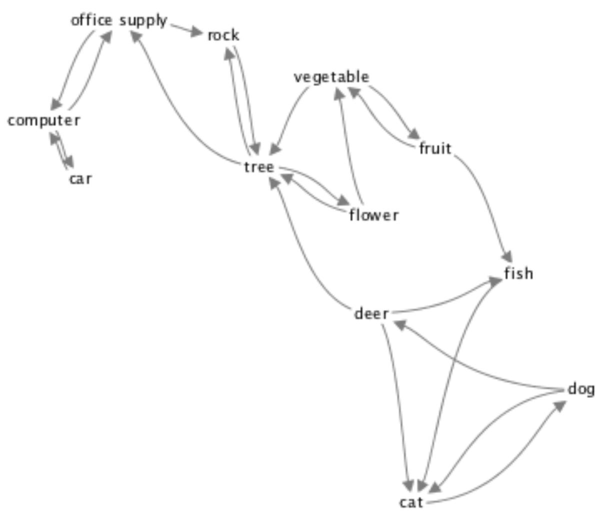
APPENDIX

Appendix A

Experiment 2A Pathfinder Network Information

Display Network



Network Information
#Nodes: 12
#Links: 22
#Loops: 0
Coherence= .81
Directed?: True

Links

from	to	from	to	directed?	distance	similarity
0	1	dog	cat	true	0.27	42.03
0	2	dog	deer	true	5.73	36.57
1	0	cat	dog	true	0.0	42.3
2	1	deer	cat	true	6.12	36.18
2	3	deer	fish	true	22.7	19.6
2	5	deer	tree	true	35.41	6.89
3	1	fish	cat	true	21.12	21.18
4	5	flower	tree	true	5.34	36.96
4	6	flower	vegetable	true	14.97	27.33
5	4	tree	flower	true	3.46	38.84
5	9	tree	office supply	true	29.08	13.22
5	11	tree	rock	true	38.54	3.76
6	5	vegetable	tree	true	10.59	31.71
6	7	vegetable	fruit	true	3.94	38.36
7	3	fruit	fish	true	37.1	5.2
7	6	fruit	vegetable	true	4.16	38.14
8	9	computer	office supply	true	29.15	13.15
8	10	computer	car	true	32.41	9.89
9	8	office supply	computer	true	28.18	14.12
9	11	office supply	rock	true	41.3	1.0
10	8	car	computer	true	34.85	7.45
11	5	rock	tree	true	36.49	5.81