## Title
The Spontaneous Use of Perceptual Representations during Conceptual Processing



Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 17(0)

Authors
Olseth, Karen L.
Barsalou, Lawrence W .

Publication Date
1995

# The Spontaneous Use of Perceptual Representations during Conceptual Processing

**Karen L. Olseth**
Department of Psychology
5848 S. University Ave.
University of Chicago
Chicago, IL 60637
klol@ccp.uchicago.edu

**Lawrence W. Barsalou**
Department of Psychology
5848 S. University Ave.
University of Chicago
Chicago, IL 60637
L-Barsalou@uchicago.edu

**Abstract**

Although both propositional and perceptual representations are viewed as central to human memory, propositional representations are typically assumed to underlie conceptual knowledge. Propositional models of concepts, such as feature lists, frames, and networks, embody this assumption. Recent theories across the cognitive sciences, however, have proposed that perceptual representations are central to conceptual processing. These perceptual representations are postulated to be schematic, dynamic, and multimodal images that have been extracted from perception and experience. In the experiment reported here, we used the property verification task to determine the extent to which people use perceptual representations during conceptual processing. A regression analysis revealed two kinds of evidence for the spontaneous use of perceptual representations: First, neutral and imagery subjects showed a similar pattern of reaction times on the task. Second, perceptual variables, such as the property size, predicted verification times.

Although human memory is often viewed as containing both propositional and perceptual representations, conceptual knowledge is typically viewed as being exclusively propositional. Recent theories across the cognitive sciences, however, have proposed that perceptual representations are central to conceptual knowledge. In the experiment reported here, we examine this possibility using a classic conceptual task: property verification. When people verify that *cars* have *wheels* and that *cats* have *claws*, do they examine perceptual representations, or do they retrieve these properties from propositional representations? To answer this question, we examined two potential sources of evidence: *instructional equivalence* and *perceptual work*. According to instructional equivalence, if neutral subjects adopt perceptual representations spontaneously, these subjects should perform similarly to imagery subjects who have been instructed explicitly to use perceptual representations. According to perceptual work, the performance of neutral subjects should be affected by perceptual factors, if these subjects adopt perceptual representations spontaneously. In the experiment to follow, we looked for evidence of instructional equivalence and perceptual work in the property verification task.

**Background.** Propositional models share the assumption that arbitrary and amodal symbols represent conceptual knowledge (e.g., Collins & Loftus, 1975; Collins & Michalski, 1989; Kintsch & van Dijk, 1978; Lenat & Guha, 1989; Smith, Shoben, & Rips, 1974). Comparable to words in a language, propositions are arbitrary because they bear no analogical resemblance to their referents, being linked through convention instead. Propositions are amodal because they represent information in the same abstract format regardless of the manner in which it was experienced. Propositional models have appealed to cognitive scientists for a variety reasons, including their ability to account for gist, their productivity, and their implementability (for reviews, see Barsalou, 1993; Barsalou, Yeh, Luka, Olseth, Mix, & Wu, 1993; Barsalou & Prinz, in press). However, propositional models also exhibit a variety of difficulties, such as failing to account for the transduction of symbols from perception, the grounding of symbols in their referents, and a principled means for identifying the symbols to include in conceptual representations.

In response to these problems, researchers across the cognitive sciences are exploring perceptual symbol systems increasingly (e.g., Barsalou, 1993; Barsalou et al., 1993; Barsalou & Prinz, in press; Barwise & Etchemendy, 1991; Edelman & Reeke, 1990; Fauconnier, 1985; Glasgow, 1993; Larkin & Simon, 1987; Mandler, 1992; Glenberg, 1995; Jackendoff, 1987; Lakoff & Johnson, 1980; Langacker, 1986; Talmy, 1983). In contrast to propositional symbols, perceptual symbols are analytic schematic images. Because perceptual symbols are extracted from the perceptions of objects, events, and introspection, they retain spatial, relational, and experiential qualities. Rather than being transduced into an arbitrary and amodal language of thought, these embodied symbols resemble their referents. Although perceptual symbols are depictive and modality specific in nature, they are not holistic, static 'pictures in the head' nor veridical copies of perceptions. Instead, they are often schematic and sparse, only containing information that has been selectively attended to during perception. Additionally, perceptual symbols are dynamic, capable of representing events as well as objects, and they are multimodal, drawn from introspection as well as from all of the perceptual modalities, not just vision. Finally, perceptual symbols are productive: From a finite set of perceptual symbols, an infinite set of complex perceptual representations can be constructed that are related to one another systematically (cf. Fodor & Pylyshyn, 1988).

Because people could potentially use either propositional or perceptual representations during conceptual processing, which do they use? In a classic study, Kosslyn (1976) had subjects perform the property verification task and found that, when subjects received explicit instructions to use imagery, they verified properties by constructing and scanning images. Because the size of a property determined the time to verify it, Kosslyn concluded that these subjects were using perceptual representations. Importantly, however, when neutral subjects received no imagery instructions and were allowed to adopt strategies spontaneously, they did not appear to use perceptual representations. Rather than size predicting verification time, associative strength between concepts and properties was critical, consistent with propositional models. On the basis of these results, Kosslyn concluded that people normally use propositional representations in conceptual tasks but can adopt perceptual representations when instructed.

Kosslyn's results for neutral subjects, however, do not necessarily imply the use of propositional representations. Instead, these results might simply reflect the fact that neutral subjects did not have to perform conceptual processing. If subjects had exploited the fact that the distractors in these experiments were unrelated to the concepts (e.g., *MOUSE-stinger*), they could have simply responded "true" when the two words were linguistically associated (e.g., *MOUSE-whiskers*), thereby performing the task without accessing conceptual representations. A simple associative strategy that capitalizes on linguistic relations would have been sufficient.

To examine this possibility, the study reported here manipulated distractor relatedness. Half the subjects received unrelated distractors (e.g., *LION-wire*), similar to Kosslyn's subjects. The remaining subjects received related distractors (e.g., *LION-jungle*) to ensure that they verified parts conceptually, not using an associative linguistic strategy. If related distractors force subjects to use conceptual processing, and if conceptual representations are perceptual, then we should find that perceptual factors predict performance, even though subjects are not instructed to use imagery. Because previous research has demonstrated the importance of distractor relatedness in conceptual processing, we suspected that this could be an important factor here (McCloskey & Glucksberg, 1979; Smith, Shoben, & Rips, 1974).

Once we ensure that subjects perform conceptual processing, we need to determine whether they are using perceptual representations. To answer this question, we examined two sources of evidence: *instructional equivalence* and *perceptual work*. Testing for instructional equivalence involved comparing the performance of *imagery subjects*, who were explicitly told to use imagery, with *neutral subjects*, who were given no instructions to use imagery. Instructional equivalence holds when neutral subjects perform the same as imagery subjects. Because much research has shown that subjects adopt imagery when instructed (e.g., Kosslyn, 1976; Kosslyn, 1980; Finke, 1989), instructional equivalence would imply that neutral subjects are using perceptual representations as well. Note that perceptual representations need not be conscious but could easily function unconsciously (Barsalou et al., 1993).

Assessing perceptual work, the second potential source of evidence for perceptual representations, involved seeing whether perceptual variables affect verification times. Of interest is whether factors such as the size, position, and visibility of a property affect the time to verify it. The more 'perceptual work' involved in processing a property, the longer it should take to verify. To examine this possibility, we scaled all concept-part pairs on 11 perceptual factors, and then regressed the verification times onto them. If neutral subjects use perceptual representations, then the perceptual factors should predict performance, just as they should for imagery subjects (i.e., instructional equivalence). To examine the extent to which subjects used non-perceptual information, such as concept-to-property strength, the concept-part pairs were scaled on linguistic factors as well.

Thus, this experiment included two orthogonal, between-subjects manipulations: unrelated vs. related distractors and neutral vs. imagery instructions. For the unrelated neutral group, we expected that only associative factors, not perceptual factors, would predict performance, because these subjects could use a simple associative strategy that did not require perceptual knowledge. In contrast, we expected that perceptual factors would predict performance for the related neutral group, because the related distractors would force subjects to use conceptual representations that were perceptual. Finally, we expected perceptual factors to predict performance of the two imagery groups, because imagery instructions typically induce the use of such representations.

## Method

**Subjects and design.** Subjects were 44 University of Chicago students who participated for pay. Eleven subjects were nested in each cell of the unrelated/related distractors X neutral/imagery instructions design. Four additional subjects' data were excluded because of error rates exceeding 20%. The average error rate for the remaining subjects was 9%. (These error rates are somewhat high, because subjects did not receive feedback about the correctness of their responses during the experiment.)

**Materials.** For the true materials, 47 concepts (e.g., *cat, phone, blouse*) from a wide variety of superordinate categories (e.g., *mammals, electronic equipment, clothes*) were paired with 112 parts (e.g., *claw, receiver, sleeve*). Each concept was paired with one to four parts, but each part was only presented once. For the false materials, two sets of 112 false properties were paired with the same 47 concepts used for the true materials. One set of false properties was highly related to the target concepts, whereas the other set was unrelated. The highly related false properties included thematically related entities (e.g., *CAR-garage, OWL-tree*), taxonomically related categories (e.g., *CAR-vehicle, OWL-bird*), and parts of other taxonomically related categories (e.g., *CAR-propeller, OWL-bill*).

Unrelated properties were entities, categories, and parts not related to the target concept (e.g., *CAR-dress*, *OWL-brick*). Ratings by independent judges verified the different relatedness of these two property sets. Each concept was paired with one to four false properties in order to ensure that subjects could not anticipate the ratio between true and false properties.

For the practice trials, 38 true concept-part pairs were constructed similar to the materials for the critical trials. Two sets of 38 false concept-property pairs (related and unrelated) were also constructed. None of the practice materials were repeated in the critical phase of the experiment.

**Predictor variables.** The 112 true concept-part pairs were scaled extensively on two sets of predictors: perceptual work and linguistic processing. The pairs were also scaled on a variety of predictors related to expectancy and part goodness, which are not included because they played relatively minor roles. Table 1 presents the perceptual and linguistic predictors examined here. Except for the lx_ltrs and lx_frq predictors, these predictors were collected from independent groups of subjects. In the regressions to follow, the verification times in each of the four critical conditions were regressed onto the 15 predictors in Table 1 to examine the critical hypotheses.[1]

**Procedure.** Subjects performed the task on Macintosh IIci computers running PsyScope and using CMU button boxes that measure millisecond accuracy. During the task, subjects rested their forefingers on two response buttons 7 cm apart, and rested a foot on a floor pedal. To initiate each trial, subjects focused their attention on an asterisk in the middle of the screen and pressed the pedal. The concept word appeared for 500 ms, followed by the true or false property 1200 ms later. Verification time was measured from the onset of the property to the detection of a response. If the property was a *physical part* of the target concept, subjects were to respond by pressing the "true" button; otherwise, they were to press the "false" button. Subjects used their dominant hand to make "true" responses. Subjects were instructed to respond as quickly as possible but to avoid making errors. Subjects received no feedback regarding the correctness of their responses, so that we would avoid imposing our biases about 'parthood' onto subjects during the experiment.

Subjects performed 76 practice trials in all. To ensure optimal performance on the critical trials, subjects were led to believe that the last 60 practice trials were critical. Subjects then performed the 224 critical trials, receiving 8 breaks spread out evenly over the 300 trials. Within the practice and critical materials, trials were presented in a different random order for each subject.

The two imagery groups received explicit instructions to form an image of the target concept and then to look for the part on the image. If they found the part, they were told to respond "true," otherwise to respond "false." Imagery subjects were exhorted to base each response on their image, even if they knew the answer without consulting it. The two neutral groups of subjects received no explicit instructions regarding strategy.

## Results

**Mean reaction times.** Before reporting the primary results of interest from the regression analysis, we present a preliminary analysis of the mean verification times. In this, and all later analyses, the reaction times for errors are removed, as well as outliers (two standard deviations above or below the mean response time for each individual subject). As Table 2 illustrates, instructions had a main effect on mean verification time ($F(1,444)=50.56$, $p<.001$). The two imagery conditions were 130 msec slower than the two neutral conditions, replicating previous results that forming conscious images generally takes longer than other processing strategies. Surprisingly, distractor relatedness had no effect on true verification time ($F(1,444)=.09$), nor did it interact with instructions ($F(1,444)=.06$). Lack of any difference in error rates indicates that a speed-accuracy tradeoff was not responsible. Although distractor relatedness had no effect on true verification time, we shall see that it had considerable impact on the regressions. As Table 2 further illustrates, distractor relatedness did affect false verification times ($F(1,444)=46.97$, $p<.001$), with the related distractors being more difficult to reject than the unrelated distractors. The higher error rates for the related distractor condition further support this conclusion ($F(1,444)=45.55$, $p<.001$), as well as indicating no speed-accuracy tradeoff.

**Regressions.** Of primary interest were differences in how the verification times from each of the four critical conditions regressed onto the predictors in Table 1. We performed these regressions in a wide variety of manners to ensure generality, with all variants pointing to the same basic conclusions. The regressions we report here are four hierarchical regressions, one for each critical cell of the design. In each regression, the mean verification times for the 112 true parts in that condition were regressed onto the two clusters of predictors in Table 1 (i.e., perceptual and linguistic). Of interest was the increase in variance accounted for ($R^2$) as each complete set of predictors was entered. Because the cluster of predictors entered first always captured any shared variance, the four linguistic predictors were entered first to enable a conservative test of the perceptual hypothesis (regressions in which the eleven perceptual predictors were entered first led to the same conclusions, as did regressions in which the two sets were allowed to enter freely, either hierarchically or non-

[1] To examine relations between the 15 predictors, correlations were calculated between them. Given the complexity in the pattern of correlations, a factor analysis was performed to establish clusters of predictors, with three general clusters observed: positional and size predictors for perceptual work, the remaining perceptual work predictors, the linguistic predictors. This scaling of the predictors ensures that the perceptual work and linguistic predictors measure distinct types of processing in the critical regressions.

*Table 1. Predictors used in the regressions.*

| Predictor | Description | Rating Scale | N* | ROM** |
|---|---|---|---|---|
| **Perceptual predictors** | | | | |
| pw_center | distance between the center of the object and part | distance in .1 inch units | 10 | .83 |
| pw_top | distance from the object's top edgeto the part | distance in .1 inch units | 10 | .86 |
| pw_left | distance from the object's left edge to the part | distance in .1 inch units | 10 | .84 |
| pw_inside | whether the part is inside the object | 0 (inside), 1 (outside) | 10 | .93 |
| pw_area | area of the part in the image space | area in .1 square inch units | 10 | .85 |
| pw_length | length of the part in the image space | distance in .1 inch units | 10 | .93 |
| pw_image | whether the part was in the initial image of the concept | 0 (not in image), 1 (in image) | 10 | .85 |
| pw_sal | salience of the part in the image | 1 (low), 2 (med), 3 (high) | 12 | .85 |
| pw_find | ease of finding the part in the image | 1 (very easy) to 9 (very diff) | 12 | .77 |
| pw_attn | likelihood of attending to the part on seeing the object | 0 (not attend), 1-3 (low-high) | 12 | .90 |
| pw_hand | likelihood of touching the part on encountering the object | 0 (not touch), 1-3 (low-high) | 12 | .68 |
| **Linguistic predictors** | | | | |
| lx_c_p | associative strength from concept word to part word | 1 (Not at all) to 9 (highly) | 20 | .88 |
| lx_p_c | associative strength from part word to concept word | 1-3 (output pos.), 4 (not produced) | 12 | .92 |
| lx_letrs | number of letters in the part word | number of letters in the word | -- | -- |
| lx_frq | word frequency of the part word | word freq. from Kucera & Francis | -- | -- |

* Number of subjects providing ratings

** Reliability of the means

*Table 2. Average verification times for correct trials, and error rates.*

| Condition | Correct Verification Time | | Error Rates | |
|---|---|---|---|---|
| | True | False | True | False |
| Unrelated Neutral | 898 | 836 | .10 | .01 |
| Unrelated Imagery | 1028 | 900 | .09 | .01 |
| Related Neutral | 900 | 947 | .09 | .07 |
| Related Imagery | 1038 | 996 | .07 | .10 |

hierarchically). Thus, any variance accounted for by the perceptual predictors in these particular regressions is variance that remains after linguistic variance has been removed. As Table 3 illustrates, the linguistic predictors only accounted for significant variance in the two unrelated conditions. In these two conditions, the two associative predictors (lx_c_p and lx_p_c) accounted for most of the variance. These results indicate that when the distractors were easy to reject, subjects used a superficial linguistic strategy that capitalized on the associative strength between the concepts and parts: If the concept and part words were associated, subjects responded "true," otherwise they responded "false." Contrary to Kosslyn (1976), even imagery subjects appeared to use this strategy when the distractors were unrelated. Even though these subjects were told to use imagery, they still used an associative strategy, because the distractors allowed it. In contrast, when the distractors were related and difficult to reject, the linguistic variables did not predict performance in either the neutral or imagery condition. The related distractors successfully blocked subjects' use of an associative strategy, forcing them to process the materials conceptually.

Of primary interest is how subjects verified parts when the associative linguistic strategy was blocked. As Table 3 illustrates, perceptual work predictors accounted for subjects' performance in the related neutral condition. Even though the perceptual predictors were entered after the linguistic predictors and thus do not include shared variance, they nevertheless accounted for a significant amount of variance in subjects' performance. Indeed, we haven't been able to find any other variables, many of which are not discussed here, that do a better job. Not only do we see an effect of perceptual work in the related neutral condition, we also observe a qualitative approximation of instructional equivalence: Like the performance of related neutral subjects, the performance of related imagery subjects is explained only by perceptual predictors and not by linguistic predictors.

Effects of perceptual work were also observed in the unrelated imagery condition. As already noted, however, linguistic variables affected the performance of this group as well. Thus, unrelated imagery subjects used both strategies. These subjects used imagery to some extent, because they were instructed to do so, but they also used the associative strategy, because the distractors allowed it.[2]

## Discussion

The regression results demonstrate a strong effect of distractor relatedness. Whereas the linguistic predictors accounted for variance when the distractors were unrelated, they failed to account for variance when the distractors were related. When distractors were unrelated, subjects used the associative strength between concept and part words as a heuristic strategy. When related distractors precluded using this strategy, however, subjects were forced to retrieve and process conceptual representations. Interestingly and significantly, these conceptual representations appeared to contain perceptual content, given the importance of perceptual predictors in both of the related distractors conditions. Even when subjects did not receive imagery instructions, they nevertheless used perceptual representations when the distractors forced conceptual processing. In summary, the presence of both instructional equivalence and perceptual work in our data indicate that neutral subjects spontaneously adopt perceptual representations in conceptual tasks.

[2] The particular perceptual predictors that accounted for the most variance varied somewhat from regression to regression. In general, however, the important predictors tended to be pw_find, pw_length, pw_image, pw_salience, pw_handle, and pw_top. Because these factors tended to be intercorrelated, it is difficult to determine which is most important.

*Table 3. Change in $R^2$ due to adding a cluster of predictors.*

| Predictor set | Condition | | | |
|---|---|---|---|---|
| | Unrelated Neutral | Unrelated Imagery | Related Neutral | Related Imagery |
| Linguistic | .16** | .16** | .06 | .06 |
| Perceptual | .10 | .15* | .18* | .29** |

* $p<.05$, ** $p<.01$

Although these results provide evidence for perceptual representations, they do not preclude the possibility that people use propositional representations in other task contexts. Wu and Barsalou (1995), however, have also found strong evidence for perceptual symbols in feature production. In this slower and more sequential conceptual task, both instructional equivalence and perceptual work were again observed. Several lines of evidence in these studies indicate that subjects scan images to produce features from conceptual combinations as well as from simple concepts. Similarly, in another line of research, we have found that the perceptual similarity of parts affects priming during part verification (Olseth & Barsalou, 1995). When subjects verify that a *DOG* has a *face*, they are faster after having previously verified *WOLF-face* than *HUMAN-face*. Because dog faces are more similar to wolf faces than human faces, more priming occurs from wolf faces than from human faces (a control condition rules out the possibility that category similarity is responsible). Thus, results from a variety of studies increasingly indicate the central role of perceptual representations in conceptual tasks.

## Acknowledgments

Work on the research reported in this paper was supported by National Science Foundation Grant SBR-9421326

## References

Barsalou, L.W. (1993). Flexibility, structure, and linguistic vagary in concepts: Manifestations of a compositional system of perceptual symbols. In A.C. Collins, S.E. Gathercole, & M.A. Conway (Eds.), *Theories of memories* (29-101). London: Erlbaum.

Barsalou, L.W., Yeh, W., Luka, B.J., Olseth, K.L., Mix, K.S., & Wu, L. (1993). Concepts and meaning. In K. Beals, G. Cooke, D. Kathman, K.E. McCullough, S. Kita, & D. Testen (Eds.), *Chicago Linguistics Society 29: Papers from the parasession on conceptual representations*. University of Chicago: Chicago Linguistics Society.

Barsalou, L.W., & Prinz, J.J. (in press). Mundane Creativity in Perceptual Symbol Systems. In T.B. Ward, S.M. Smith, & J. Vaid (Eds.), *Conceptual structures and processes: Emergence, discovery, and change*. Washington, DC: American Psychological Associations.

Barwise, J., & Etchemendy, J. (1991). Visual information and valid reasoning. In. W. Zimmerman & S. Cunningham (Eds.), *Visualization in mathematics* (9-24). Washington: Mathematical Association of America.

Collins, A.M., & Loftus, E.F. (1975). A spreading activation theory of semantic processing. *Psychological Review, 82*, 407-428.

Collins, A.M., & Michalski, R. (1989). The logic of plausible reasoning: A core theory. *Cognitive Science, 13*, 1-50.

Edelman, G.M., & Reeke, G.N, Jr. (1990). Is it possible to construct a perception machine? *Proceedings of the American Philosophical Society, 134*, 36-73.

Fauconnier, G. (1985). *Mental spaces*. Cambridge, MA: MIT Press.

Finke, R.A. (1989). *Principles of mental imagery*. Cambridge, MA: MIT Press.

Fodor, J.A., & Pylyshyn, Z.W. (1988). Connectionism and cognitive architecture: A critical analysis. *Cognition, 28*, 3-71

Glasgow, J.I. (1993). The imagery debate revisited: A computational perspective. *Computational Intelligence, 9*, 309-333.

Glenberg, A.M. (1994). What is memory for. Manuscript under review.

Jackendoff, R. (1987). On beyond zebra: The relation of linguistic and visual information. *Cognition, 26*, 89-114.

Kintsch, W., & van Dijk, T.A. (1978). Toward a model of text comprehension and production. *Psychological Review, 85*, 363-394.

Kosslyn, S.M. (1976). Can imagery be distinguished from other forms of internal representation? Evidence from studies of information retrieval times. *Memory & Cognition, 4*, 291-297.

Kosslyn, S.M. (1980). *Image and mind*. Cambridge, MA: Harvard University Press.

Lakoff, G., & Johnson, M. (1980). *Metaphors we live by*. Chicago: University of Chicago Press.

Langacker, R.W. (1986). An introduction to cognitive grammar. *Cognitive Science, 10*, 1-40.

Larkin, J.H., & Simon, H.A. (1987). Why a diagram is (sometimes) worth ten thousand words. *Cognitive Science, 11*, 65-100.

Lenat, D.B., & Guha, R.V. (1989). *Building large knowledge-based systems: Representation and inference in the Cyc project*. Reading, MA: Addison-Wesley.

Mandler, J.M. (1992). How to build a baby: II. Conceptual primitives. *Psychological Review, 99*, 587-604.

McCloskey, M., & Glucksberg, S. (1979). Decision processes in verifying category membership statements: Implications for models of semantic memory. *Cognitive Psychology, 11*, 1-37.

Olseth, K.L., & Barsalou, L.W. (1995). Work in progress.

Smith, E.E., Shoben, E.J., & Rips, L.J. (1974). Structure and process in semantic memory: A featural model for semantic decisions. *Psychological Review, 81*, 214-241.

Wu, L., & Barsalou, L.W. (1995). Work in progress.