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Short article

Multifactorial context effects on visual recognition memory

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While effects of contextual change or constancy on memory are widely found when tested by free and cued recall, there is greater inconsistency in context effects on recognition. This study employed a paradigm maximizing target–context interactivity and specificity to reveal three levels of context effects on successful retrieval, as well as context effects on the generation of false alarms, thereby revealing separable contributions of target–context binding, additive familiarity, and configural constancy. The separability of these factors enables the use of memory context effects as tools for investigating associative memory.

Adaptive behaviour requires the ability to perceive and create representations in memory not only for individual items in our environment, but also for the associative and dissociative relationships between them. Research into the roles of associations in human memory may employ two experimental approaches. On one hand, it is possible to create tasks requiring pair-associate learning and to subsequently directly test for memory of those associations. This can be done by presenting one member of a studied pair as a cue for the recall of the other (e.g., Meltzer & Constable, 2005; Vakil & Oded, 2003), or by a recognition test in which original and recombined pairs are to be discriminated (e.g., Stark & Squire, 2003). When there is attentional inequality between the experienced stimuli (e.g., when one was at the focus of attention, such as a visually presented word on which a semantic judgement was made, and the other was the coloured screen on which that

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word was seen), direct memory for the focal item's context is often called "source memory" (Johnson, Hashtroudi, & Lindsay, 1993).

Memory for associations may also be assessed *indirectly*, by measuring the impact on memory for one experienced stimulus of the repeated presentation or absence of stimuli that originally accompanied it. Such effects of contextual constancy or change on memory for studied materials—that is, *context effects* (CEs)—are widely found when target memory is tested by free recall (e.g., Parker & Gellatly; 1997) and cued recall (e.g., Smith, Glenberg, & Bjork, 1978). However, there is greater inconsistency in reports about CEs in recognition memory tests (CEs reported, e.g., by Hollingworth, 2006; Russo, Ward, Geurts, & Scheres, 1999; but not found, e.g., by Fernandez & Glenberg, 1985; Godden & Baddeley, 1980; Murnane & Phelps, 1993, 1994). There have been several attempts to address this discrepancy. For example, the global activation approach, which views memory as reflecting the summation of activation of encoding event representations, claims that an old context presented in recognition tests along with a new foil may lead to false endorsement of foils as old. Therefore, CE benefits would emerge only when totally new contexts are contrasted with old contexts for both targets and foils (Murnane & Phelps, 1994). Another approach posits that CEs emerge in recognition only for totally novel stimuli, since for items that are very familiar from past experience existing representations may be employed to construct a strong episodic trace at encoding, obviating the need for contextual information (Dalton, 1993; Russo et al., 1999). Smith and Vela (2001) suggest that CEs are attenuated when targets are easily remembered, a phenomenon they call "outshining". Since recognition tasks are generally easier than recall tasks, CEs are less likely to be found in recognition memory studies. Finally, building upon dual-process theories of recognition, Macken (2002) suggested that CEs obtain only for the recollective aspect of recognition but not for its familiarity aspect.

All these approaches have attractive features. However, none of them are in total accord with the empirical findings (see Macken, 2002, and below). A full account of CEs in recognition would seem to require an integrative approach that stresses the multifactorial nature of recognition CEs. Chief among these are factors that affect the nature and strength of the target–context binding: *interactivity* and *specificity*. Target–context interactivity at study (Baddeley, 1982) may be induced by top-down processes (e.g., by instructing participants to perform a cognitive operation requiring comparison or joint mental manipulation of the two stimuli) or bottom-up processes (e.g., by presenting target–context pairs that are automatically assessed relationally). An example of top-down processes may be found in the study of Winograd and Rivers-Bulkeley (1977), who presented pairs of male and female photographs and asked participants to judge either how much they liked each one of the faces presented (independent context) or how compatible they were as a couple (interactive context). CEs on recognition memory were found in the interactive but not in the independent context condition. An example of bottom-up processes is the viewing of a picture of a person wearing a uniform, in which "the clothes make the man". Target–context specificity (Dalton, 1993) is the one-to-one correspondence between target and context, as opposed to having one context linked with many targets or vice versa. Also seemingly relevant to the effects of local context on recognition memory are characteristics affecting individual familiarity strength of target and context stimuli. Furthermore, CEs may differ based on level of context: environmental, local (e.g., stimuli co-occurring within a study array, such as two words or two pictures), or within-stimulus characteristics, such as font colour or speaker voice (Smith & Vela, 2001). Clarification of the effects of these factors on recognition memory CEs is important, as recognition provides a more flexible platform than recall tests for the study of CEs under various retrieval conditions, enabling effective investigation of the cognitive and brain bases of associative memory.

The present study attempts to explicate the multifactorial effects of context on memory by establishing an effective paradigm for eliciting CEs on recognition memory. We employed a local-context stimulus array, presenting participants with photographs of trial-unique male faces portrayed as wearing distinctive, trial-unique hats (yielding specificity). The instructed task was to rate the compatibility of the faces and the hats (yielding interactive processing), and the participants were instructed to remember the faces for a subsequent memory test but not instructed to remember the hats (yielding attentional inequality and a target–context relationship). Since faces may naturally capture attention more than other visual objects (Hershler & Hochstein, 2005), and the faces were the instructed memory targets, there was consonance between bottom-up and top-down target–context role assignment.

We use this paradigm to address the suggestion that CEs may be attributed to the summation of activation of encoding event representations (i.e., the global activation approach, e.g., Murnane & Phelps, 1994). That view predicts that CE benefits would emerge only when test trials containing completely new contexts are contrasted with test trials containing old contexts. We compared the CE benefit to recognition of exact target–context repetitions ("repeat condition") with CE benefit to memory for targets recombined with contexts that were seen previously but paired with different targets ("re-pair condition"). If CEs are driven only by additive familiarity, equal benefit should be seen for these conditions. However, if recollection (or associative familiarity; Mayes et al., 2004) of the target–context pairing further aids recognition of the target, greater benefit will be found for the original pairings. Such an advantage of the repeat over the re-pair condition is also predicted by the ICE (item, context, ensemble) theory of CEs (Murnane, Phelps, & Malmberg, 1999).

A further characterization of CEs was attempted by using two different "context-negative" conditions. In the "new" condition, targets were accompanied by contexts that had not been seen at study. This condition is not completely neutral, since the presence of the novel contextual stimulus preserves the stimulus array structure—that is, the face seen at study topped by a hat is once again seen topped by a hat, even though it is a novel hat. This is a two-edged sword, however, since the unfamiliarity of the context stimulus may bias the observer to judge the target unfamiliar as well. Therefore we also included the "None" condition, of faces without hats, which on one hand breaks the study–test array structure consistency, but abstains from introducing a different, potentially disruptive bias.

The effects of context reinstatement on the evaluation of new target stimuli (correct rejection vs. false alarms) are another index of memory for contextual information. If the presentation of previously seen context stimuli biases the observer to misjudge new targets as having been previously seen, one may infer that those context stimuli were remembered. This kind of CEs parallels the re-pair condition for old targets, in the sense that additive familiarity of target and context influences the memory judgement. In principle, these effects might be equipotent. This would lead to a situation in which context reinstatement leads to no net benefit to memory performance; however, the reason for this lack would not be that contexts are not remembered, but that they are remembered equally well in conjunction with both old and new targets. It is therefore insufficient to assess associative aspects of memory as expressed through CEs using a combined overall score such as percentage correct or d', as those measures mask the potential ability of context reinstatement to increase both the number of hits and the number of false alarms. Accordingly, in addition to d', we report and analyse data for old targets (hits vs. misses) and new targets (false alarms vs. correct rejections) separately.

METHOD

Participants

Participants were 28 young adults (8 males; mean age 23.1 years, range 18–32 years), self-reportedly in good health, with normal or adjusted-to-normal vision. These participants included undergraduate students at Bar-Ilan University who took part in the experiment to fulfil academic requirements and others who volunteered in return for payment. Written informed consent was obtained from all participants for a protocol approved by the Bar-Ilan University Institutional Review Board.

Materials

Stimuli consisted of 64 monochrome photographs of hat-topped but otherwise full faces of adult males, each 7 × 10 cm in size, and 52 monochrome photographs of hats, 3 × 3 cm in size. The hats were characteristic of types of work—for example, police, firefighter, cook; or of cultural characters or types—for example, Napoleon, Peter Pan, a witch; an example is provided in Figure 1. Each hat was correctly identified by at least 80% of 30 raters (not experimental participants) in a separate pretest. These stimuli were randomly paired to form 32 face–hat study pairs, and an additional 32 faces and 32 hats supplemented them to form the various test pair combinations. Two different combination sets were created in this manner, and each set formed the target pairs for half the participants. These two sets did not yield different accuracy rates or response times, so they were combined for all subsequent analyses.

Seven types of face–hat photo pairs or face-only photos were presented at test, each forming a different test condition:

1. A total of 8 of the originally studied pairs (target old, context old–same, TOCO-S; “repeat” condition).
2. A total of 8 pairs in which a studied target face was presented in the context of a hat that had been seen at study with a different face (target old, context old–different, TOCO-D; “repair” condition).
3. A total of 8 pairs in which a studied target face was presented in the context of a new hat that had not been seen at study (target old, context new, TOCN; “new” condition).
4. A total of 8 studied target faces unaccompanied by any hat (target old, TO; “none” condition).
5. A total of 8 new unstudied faces presented in the context of a hat that had been seen at study with a different face (target new, context old, TNCO).
6. A total of 12 pairs of new, unstudied faces and hats (target new, context new, TNCN).
7. A total of 12 new unstudied faces unaccompanied by any hat (target new, TN).
8. For a separate test of direct memory for context, 8 studied hats that did not appear in the other trial types were paired with 8 unstudied foil hats (context direct).

Procedure

In the encoding phase, 32 face–hat pairs were presented to participants on a computer screen by SuperLab (Cedrus, Inc.) for 4 s each, and participants were instructed to rate face–hat compatibility by verbal response, using a scale of 1–5. They were also instructed to remember the faces for a subsequent memory test. Each participant performed four training trials before beginning the experiment.

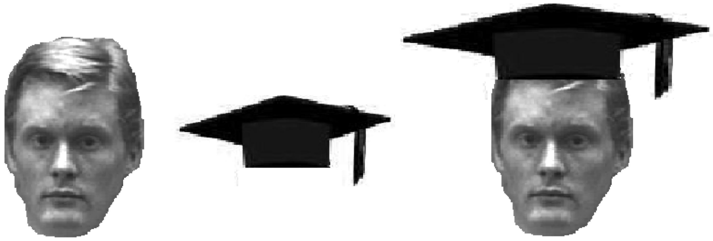

Figure 1. *Examples of face–hat stimulus pairs employed in this study.*

The encoding session was followed immediately by the test session. Participants were told that they would see studied and unstudied faces, accompanied by the same or different studied and unstudied hats. They were instructed to indicate by key press, as quickly and accurately as possible, whether the face had been seen at study (old) or not (new), irrespective of the hat now accompanying it. Participants were instructed to guess if unsure. They were then shown 64 face–hat pairs or face-only photos (Types 1–7 above) in pseudorandom order. The rate of presentation of test trials was self-paced, with the response triggering the following trial.

After the face recognition test, a separate test was administered for recognition of context hats alone. Participants were shown eight pairs of photos of hats (Type 8, above), consisting of a studied context hat and an unstudied foil, and were asked to indicate by key press which of the two hats had appeared at study—that is, a two-alternative forced-choice direct appraisal of recognition memory for the context hats. If they were unsure they were instructed to guess.

The order of presentation of stimuli in both study and test phases was randomized over participants.

RESULTS

As explained above, results for hits and false alarms are first reported separately, to provide unconfounded assessments of associative memory strength. Target recognition accuracy (hits) and incorrect endorsement of foils (false alarms; FA) for the various conditions are portrayed in Figure 2. In order to evaluate the CEs on hits and on false alarms, we conducted two separate analyses of variance (ANOVAs). For hits, a one-way repeated measures ANOVA revealed a significant effect of context type, $F(3, 81) = 22.47$, $p < .01$. As can be seen in Figure 2A, the target recognition hit rate exhibits a graded trend according with the degree of context reinstatement: repeat (exact reinstatement including target–context binding; TOCO-S; 75.9%) > re-pair (additive familiarity of old target and old context but without binding; TOCO-D; 61.6%) > new (configural similarity to encoding array; TOCN; 50.9%) > none (TO; 40.2%). Pairwise contrasts revealed that all these differences were statistically significant: repeat versus re-pair, $F(1, 27) = 17.19$, $p < .01$; re-pair versus new, $F(1, 27) = 5.17$, $p < .05$; new versus none, $F(1, 27) = 4.73$, $p < .05$.

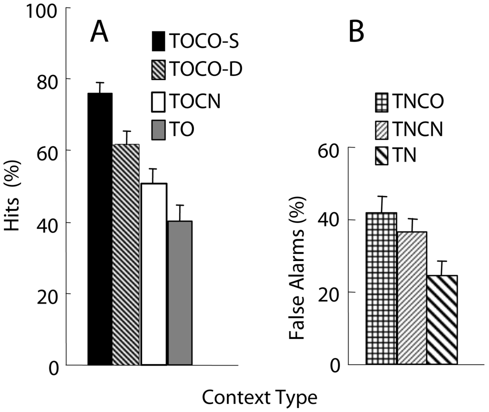

Figure 2. *Recognition memory for face targets in Experiment 1. (A) Percentage of hits in four retrieval context conditions:* TOCO-S *(target old, context old–same; "repeat");* TOCO-D *(target old, context old–different; "re-pair");* TOCN *(target old, context new; "new");* TO *(target old, i.e., no local context; "none"). (B) Percentage of false alarms to new foil faces in three retrieval context conditions:* TNCO *(target new, context old; "re-pair");* TNCN *(target new, context new; "new");* TN *(target new, i.e., no local context; "none"). Brackets indicate standard error of the mean.*

A complementary graded trend obtained for false alarms. A one-way repeated measures ANOVA revealed a significant effect of context type, $F(2, 54) = 13.1$, $p < .01$. As can be seen in Figure 2B, increasing the degree of context reinstatement accompanying the foils increased the number of false alarms: old context (TNCO; 42.0% false alarms) > new context (TNCN; 36.6% false alarms) > none (TN; 24.4% false alarms). Planned comparisons revealed that differences of old versus none and new versus none were statistically significant, ps $< .01$, but re-pair versus new was not, $p > .2$.

To assess whether context reinstatement actually benefits memory, or just creates a bias towards "old" responses for both targets and foils, we calculated mean discrimination accuracy indices using the d' statistic. We contrasted hits in each "target" condition with false alarms in the most similar "foil" condition: repeat hits with TNCO false alarms ($d' = 0.97$); re-pair hits with TNCO false alarms ($d' = 0.47$); TOCN hits with TNCN ("new–new") false alarms ($d' = 0.42$); and TO hits with TN ("none–none") false alarms ($d'=0.68$). These scores indicate that the task was challenging, with relatively low discrimination accuracies, but one-sample t tests indicated that in all conditions performance was well above chance (all ts > 2.6, and ps $< .02$). We then compared the effects of these four context conditions on d' using a repeated measures ANOVA. This indicated a significant effect of context condition, $F(3, 81) = 4.53, p < .01$. Planned contrasts revealed that the repeat condition was characterized by better discrimination accuracy than the re-pair condition, $F(1, 27) = 13.82, p < .01$, but that discrimination accuracy in the re-pair condition was not significantly great than that in the TOCN (new) condition, $F(1, 27) = 0.09, p < 1.0$. Similarly, the difference between the TOCN and the TO (none) condition was not significantly different, $F(1, 27) = 2.09, p > 0.1$. Thus, exact contextual reinstatement does indeed benefit recognition accuracy. In contrast, old contexts reappearing unbound to their original pair members raise both the hit rate for targets and the false alarm rate for foils to a similar degree, leading to no improvement in recognition accuracy relative to new contexts.

Another indication of the consistent ability of context reinstatement to increase both hits and false alarms in all but exact repetitions is the correlation between these effects across participants. We found that the degree of context-based increase of hits (re-pair vs. new) and of false alarms (TNCO vs. TNCN) were indeed correlated: Pearson product-moment correlation, $r(26) = .331, p < .05$ (one-tailed).

In the direct recognition test for context hats, participants correctly endorsed 80.6% of the previously presented context hats.

DISCUSSION

In this experiment we observed complex effects of local encoding context reinstatement on visual recognition memory. These CEs distinguished between several types of context. When the stimulus-array structure was repeated at test, even if the specific context item accompanying the target was new (the TOCN condition), a modest but significant CE obtained (relative to the TO condition)—that is, old faces are better remembered when topped with any hat than if bareheaded. This finding of the benefit of configural similarity of stimulus arrays between encoding and retrieval accords with the report of new > none CEs in memory for face pairs (Winograd & Rivers-Bulkeley, 1977). If, in addition, the test context had appeared at study, even with a different target (re-pair condition), yet additional CE was found. It is possible that such old context stimuli served to activate memories of the encoding episode as a whole, inducing recollective processes, and so indirectly cued the old targets. Alternatively, the increase in the number of correct "old" judgements in such cases may result from the additive familiarity of target and context stimuli, as would be predicted by the global activation approach (Murnane & Phelps, 1994). Finally, if targets were accompanied by the exact contexts with which they were paired at study, even more CE obtained. Arguably, this is because the context stimulus specifically cued memory for its accompanying target. This effect is in keeping with the ICE theory (Murnane et al., 1999), which posits that CEs emerge when an ensemble representation is created in addition to the separate memories for item (target) and context. This process seemingly involves hippocampal-dependent associative binding between the target and context stimuli.

Manipulation of target and context additive familiarity and target–context stimulus-array similarity also yielded different levels of false alarms in response to foils. The presence of old encoding context together with a new target increased the probability of a false alarm to target, relative to new context. Though this effect of additive familiarity as expressed through the larger number of false alarms in TNCO versus TNCN conditions was not statistically significant, this tendency is worthy of further examination. It suggests that context effect deficits yielding false alarms should be taken into account when assessing performance in memory tasks in which there is local context reinstatement. Furthermore, there was a significant difference of both TNCO and TNCN conditions versus the TN conditions—that is, a new face is significantly more likely to be misidentified as old if it is hatted (as were all the faces at study) than if it is not.

Context reinstatement improved memory discrimination accuracy (*d′*) only in cases of exact old target–context pair repetition, relative to old contexts presented with foils. This may be seen as another expression of the ensemble/binding factor of CEs. In all other cases, context reinstatement led to response bias, increasing the number of "old" responses to both targets and foils. As we noted in the Introduction, such response bias may not improve accuracy, but provides a clear index of the memory strength of the contextual information. It is instructive that in those other cases, CEs on hits and false alarms were correlated across participants. This gives weight to our suggestion that CEs may provide a response-independent assessment of context memory strength. Further examination of this process seems warranted by these initial findings.

These CEs were obtained by employing conditions conducive to target–context binding: trial-unique target–context pairings, interactive encoding, and consonance between top-down and bottom-up target–context role assignment. Earlier studies (such as those noted above) that did not use this full array did not consistently report CEs in recognition memory.

The current findings support the notion that CEs are multifactorial. Accordingly, accounts of recognition memory CEs listed above may be seen as complementary, each reflecting one aspect of the effects. The global activation account (Murnane & Phelps, 1994) may be seen as providing an explanation of the additive familiarity effect, but does not account for the added benefit of target–context binding. ICE theory (Murnane et al., 1999) related to the binding effect, but does not account for the context-based increase in false alarms in which no binding is possible (since the "target" foil was not previously seen). Putative "outshining" of contextual cues in recognition tests (Smith & Vela, 2001) may occur, but when encoding is interactive, and target–context specificity is instituted (as may often be the case in ecological remembering as well as in the paradigm here employed), CEs nonetheless robustly appear.

The diverse mnemonic processes that we have shown to contribute to CEs are probably instantiated in different brain areas. Neuropsychological and physiological studies using the CEs paradigm validated by this experiment should be helpful in illuminating the way the various CEs factors interact to produce our mnemonic abilities in our interactions with complex environments.

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