Research Report

Remembering by the Seat of Your Pants

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ABSTRACT—***According to dual-process theories of memory, ''old'' responses in recognition may reflect the separate or combined effects of two states, specific recollection and feelings of nonspecific familiarity. When decisions are based on familiarity, people may attribute enhanced perceptual fluency to memory for prior occurrence. In this experiment, we used a subliminal somatic cue to test whether a low-amplitude buzz could enhance feelings of familiarity. The buzz increased the likelihood that participants responded ''old,'' both correctly and incorrectly. This effect occurred only with subjectively difficult stimuli, those relatively unlikely to elicit clear recollection. When a stronger control buzz was used, the effect vanished. Results for confidence ratings were consistent with Whittlesea's SCAPE theory, producing a dissociation between hits and false alarms. Specifically, the buzz reduced confidence in hits and increased confidence in false alarms, in accord with the most likely attributions for the feelings of familiarity associated with the buzz.***

In a well-known experiment, Jacoby and Whitehouse (1989) showed people words for memorization. In a subsequent recognition task, test words were sometimes preceded by identity primes that were either masked (subliminal) or shown clearly. When matching primes were subliminal, "old" responses, and especially false alarms, increased. Conversely, when matching primes were overt, "old" responses decreased. Jacoby and Whitehouse explained these results in a *memory attribution* framework: With subliminal primes, people interpret enhanced perceptual fluency as familiarity (see Jacoby & Dallas, 1981). With overt primes, people discount "positive" signals (either fluency or true familiarity) as sequelae of the primes.

Recently, Whittlesea and his colleagues have outlined a general theory of memory attributions (called SCAPE) that extends beyond perceptual fluency effects. Whittlesea and Leboe (2000; Whittlesea & Williams, 1998, 2001) suggested that memory access (recognition or recall) entails two stages: First is *production* of mental states, wherein images or ideas are brought to mind. Production may follow perceptual input, such as a face, which the mind immediately elaborates (Neisser, 1967), perhaps with a name. Alternatively, production may arise from covert retrieval cues (Tulving & Thompson, 1973). Following production, the second stage is *evaluation*. This is not direct stimulus evaluation, such as deciding whether a recognition target exceeds criterion. Rather, Whittlesea (1997; Leboe & Whittlesea, 2002) proposed that during this second stage, people automatically and continuously evaluate their own production functions, keeping a running index of the relative harmony of mind.

By its nature, evaluation is relativistic, creating different subjective states of mind. For example, upon returning home after work, you immediately recognize various objects and their relative locations. Ordinarily, the evaluation process will not be unduly aroused, so no particular feelings will be created. However, suppose that upon entering, you experience mild anxiety. The production process has recognized everything, but with dysfluency that creates hesitation. You soon realize that it's cleaning day, and the maid moved things while cleaning. A moment of apprehension ("is someone here?") quickly converts to pleasure ("wow, the maid did a good job!"), as a result of successive evaluations of a momentary processing problem.

As this example suggests, SCAPE explains (sometimes contradictory) feelings by a *discrepancy-attribution* hypothesis (Whittlesea & Williams, 2001). Depending on context, people have different implicit expectations of processing fluency. When those expectations are violated, an evaluation "flag" is raised, automatically triggering a search for some explanation. In many cases, context itself provides a natural attribution. For example, in Jacoby and Whitehouse's (1989) study, inexplicable perceptual (i.e., production) fluency evoked feelings of familiarity. In a challenging recognition test, people experience trials involving easy decisions (both easy rejections and easy hits), randomly interspersed with trials requiring more difficult decisions. This encourages relatively low expectations of processing fluency;

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Fig. 1. The subliminal-signal chair as it appeared to participants (left panel) and the hidden apparatus under the chair (right panel).

momentary improvements should evoke the obvious attribution that prior experience is responsible.

According to Whittlesea and Williams (2001), when processing expectations are violated, the production process issues a nonspecific signal leading people to experience feelings of either memory or memory failure. This nonspecific signal is generally interpreted as familiarity. By linking familiarity to internal processing changes, the discrepancy-attribution hypothesis helps rationalize feelings of familiarity. Despite standard usage of the term "familiarity," truly familiar stimuli (e.g., seeing a colleague at work) generally evoke no particular feelings. Conversely, mildly familiar stimuli ("what other movie was this actor in?") create a strong, nagging sense of familiarity. In other words, feelings of familiarity often indicate precisely a failure of memory. Thus, when expectations for ease of processing are low, unexplained improvements feel like memory. When expectations for ease of processing are high, momentary decrements feel like lapses (e.g., your colleague shaved his beard, and you sense that something unknown seems "different"). Finally, when expectations (low or high) are met, people experience no "memory signals" at all.

In the present study, we tested the discrepancy-attribution hypothesis by giving people an unexplained "arousal signal" during a memory task. We anticipated that they would experience heightened familiarity when given the signal, but that their subjective feelings of confidence might change in a different, but systematic way. Our approach was inspired by Schachter and Singer (1962), who gave people epinephrine, telling them it was "suproxin," a vision enhancer. Some people were honestly warned of side effects (e.g., increased heart rate); others were not. All were then exposed to a confederate who acted happy or angry. When people anticipated side effects, they did not experience emotional changes. However, people who had no forewarning experienced the emotions modeled by the confederate: Unexplained somatic cues were attributed to contextually appropriate emotions. We anticipated a similar process in memory, with unexplained somatic cues experienced as familiarity.

Testing this hypothesis required a subtle, controllable cue. We modified a chair, affixing two wireless computer speakers underneath. The front covers were removed; woofers were secured directly to the chair (see Fig. 1). The unseen speakers were used to transmit a subliminal vibration (the buzz). In each trial block, participants memorized various materials, were briefly distracted, and then received a recognition test. In half the trials, test items were presented with a simultaneous subliminal buzz. For control participants, all procedures were identical, except that the buzz was stronger and easily perceived.[1]

To assess the generality of any effect, we used three different sets of materials. In addition to the primary manipulation (buzz presence or absence), within each set of stimuli, we manipulated their intrinsic difficulty. Participants completed three trial blocks, respectively memorizing words, pictures, and faces. For each block, we selected items such that half were relatively easy to memorize and half were more difficult. In the faces block, for example, we included photographs of celebrities and medical students. By the attribution framework, we expected that people would attribute the buzz to familiarity, so that the buzz would increase hits and false alarms. According to dual-process theories of recognition memory (e.g., Jacoby & Dallas, 1981), recognition judgments may be made on the basis of either explicit recollection or nonspecific familiarity. Thus, we expected this pattern primarily among the more difficult stimuli, which were less likely to engender recollection. We also collected confidence ratings, expecting confidence to vary according to both the buzz's presence or absence and peoples' actual performance, which

[1] One challenge of this research was its amusing nature, as debriefed students might tell others about the buzzing chair. Although an ideal experiment would have control and experimental trials within subjects, the between-subjects design helped maintain secrecy. Participants were debriefed by e-mail after the study was complete.

estimated their processing coherence. The responses of control participants were not expected to follow either pattern.

METHOD

Participants

Eighty-one Arizona State University students participated for credit (43 in the experimental condition and 38 in the control condition). Five experimental-condition participants were dropped from the analyses because they detected the signal (3 people) or failed to follow instructions (2 people), leaving 38 participants per condition.

Materials and Apparatus

The experiment comprised three study-test blocks, presenting words, pictures, and faces, respectively. In each stimulus class, 96 items were selected, 48 that were intuitively easy to remember and 48 that were harder to remember. Words were selected from published sources (Coltheart, 1981; Gilhooly & Logie, 1980): Easy words were rare, high-imagery words (e.g., *snowball*). Hard words were common, low-imagery words (e.g., *movement*). Across categories, words were matched for initial phonemes and length. For easy pictures, we selected color photographs of various objects (e.g., rubber chicken). Hard pictures were clip-art files; they formed thematically related pairs, so that for each studied picture there would be a related foil used in the test session (Homa & Vierra, 1988). Easy faces were celebrity photographs (half women). Hard faces were downloaded photographs of medical students from various universities.

The other stimuli were sound files sent through the chair. In the experimental condition, the signal was a low-amplitude, 1,500-ms, 60-Hz triangle wave. To select an appropriate tone and amplitude, we gave 20 volunteers two staircase, forced-choice tests (Cheesman & Merikle, 1986). First, they tried to discriminate two triangle waves (60-Hz, 75-Hz); these were digitally increased and decreased in amplitude for threshold estimation. Next, they tried to determine which speaker (left or right) was transmitting the 60-Hz tone, again using the threshold-estimation procedure. In every trial, participants first indicated whether they felt anything. Regardless of that response, they next guessed whether they felt signal A or signal B, or whether the signal was coming from the right or left. We operationally defined a *subliminal signal* as one that led 15 participants (75%) to claim no awareness, yet evoked guessing accuracy greater than 65% (Merikle, Smilek, & Eastwood, 2001).[2] The control signal was a higher-amplitude, 100-Hz square wave.

[2]Using a signal amplitude that 25% of participants could detect was rather liberal. However, during threshold estimation, participants were directly attending their buttocks, trying to detect a buzz. We assumed that participants in the main experiment, attending to test items, would be less sensitive.

Procedure

Participants were tested individually in a soundproof booth. The experiment included separate trial blocks (study and test) testing memory for words, pictures, and faces, respectively. In the word-learning block, each trial began with a 500-ms fixation signal (***), followed by a word shown for 2 s, then a 1-s blank screen. In the picture- and face-learning blocks, study time was reduced to 1 s, to avoid ceiling effects. Forty-eight stimuli, counterbalanced across participants, were presented for memorization in each study block.

Following each block of learning trials, participants were distracted by eight multiple-choice opinion questions (e.g., "what percentage of people are truly evil?"). Afterward, they took a recognition test with the 96 stimuli from the stimulus class (half old, half foils) in random order. In each trial, the fixation cue was followed by a test item. On buzz trials, a 1,500-ms tone was synchronized to stimulus onset, although participants had 5 s to respond. They indicated "old" or "new" by key press, then rated their confidence from 1 to 7. Tones were used evenly across old and new items, and across easy and hard items. For counterbalancing, four different versions of each test were administered to approximately equal numbers of participants.

In both the experimental and the control conditions, ambient white noise was presented throughout the session (participants were told it would minimize distraction). The two groups differed in awareness of the signal. For the control group, an easily perceptible buzz was used on buzz trials. Control participants were told that they would "sometimes feel a buzz" via the chair, but no elaboration was provided. In the experimental condition, no mention was made of the buzz. Each session ended with an open-ended query: "Do you have any questions, or did you notice anything unusual during the experiment?" Three experimental participants mentioned the signal and were excluded from analyses. All procedures followed American Psychological Association and Arizona State University guidelines for human subjects research.

RESULTS

The data were examined primarily using 2 (difficulty: easy vs. hard items) $\times$ 2 (buzz: present vs. absent) analyses of variance (ANOVAs), with a standard significance value ($p < .05$). In all analyses, qualitative and statistical patterns were similar across the three stimulus types. We therefore report overall analyses, collapsing across stimulus types.

Recognition: Experimental Group

As shown in Figure 2a, recognition of easy items was unaffected by the buzz; sensitivity and bias estimates were nearly identical for the no-buzz ($A' = .92, B'' = .18$) and buzz ($A' = .93, B'' = .13$) trials. Among hard items, buzz and no-buzz trials produced equal sensitivity ($A' = .86$). Mean sensitivity was reliably higher for

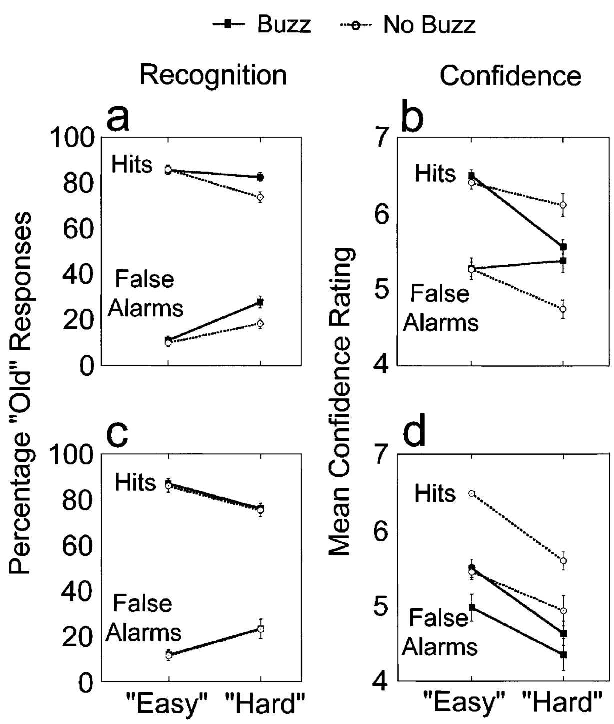

Fig. 2. Recognition and confidence results: mean hit and false alarm rates (± *SEM*) from the experimental (a) and control (c) conditions and mean confidence ratings (± *SEM*) from the experimental (b) and control (d) conditions (higher ratings indicate greater confidence). In all panels, data are collapsed across words, pictures, and faces.

easy than for difficult items, $F(1, 37) = 20.7$, $\eta_p^2 = .21$. The result of primary interest is that the buzz elicited a liberal bias shift for hard items; B'' estimates for no-buzz and buzz trials were .21 and −.33, respectively, $F(1, 37) = 31.9$, $\eta_p^2 = .44$. The Difficulty × Buzz interaction was also reliable for B'', $F(1, 37) = 15.5$, $\eta_p^2 = .17$. Following the ANOVAs, we conducted sign tests, asking how many participants (out of 38) showed liberal shifts in hard, buzz trials. In the word, picture, and face blocks, the respective counts were 30 ($p < .001$), 29 ($p < .01$), and 34 ($p < .001$).

Recognition: Control Group

In the control group, sensitivity showed a reliable difficulty effect (Fig. 2c), with sensitivity for easy items ($A' = .93$) exceeding sensitivity for hard items ($A' = .84$), $F(1, 37) = 29.0$, $\eta_p^2 - .26$. There were no reliable effects involving presence versus absence of the buzz. To verify that criteria differed across the experimental and control conditions, we combined the data: The three-way interaction (Buzz × Difficulty × Condition) was reliable, $F(2, 74) = 9.8$, $\eta_p^2 = .009$. When people were aware of the buzz, it had no effect.

Confidence Ratings: Experimental Group

As Figure 2b shows, when experimental participants made false alarms, a subliminal buzz increased their confidence. When they made hits, the buzz decreased their confidence. Participants in this condition were generally self-assured; average confidence ratings were above 4 on a 7-point scale. For hits, a difficulty effect emerged: Confidence ratings were 0.71 higher for easy than for hard items, $F(1, 37) = 21.8$, $\eta_p^2 = .33$. A similar trend (0.16 difference in ratings) was not reliable for false alarms, $F(1, 37) = 2.7$, n.s. The buzz reduced confidence in hits by 0.22, $F(1, 37) = 5.2$, $\eta_p^2 = .11$, but increased confidence in false alarms by 0.34, $F(1, 37) = 7.9$, $\eta_p^2 = .13$. The Difficulty × Buzz interaction was reliable for both hits, $F(1, 37) = 7.5$, $\eta_p^2 = .13$, and false alarms, $F(1, 37) = 6.9$, $\eta_p^2 = .09$. We again conducted sign tests: In the word, picture, and face blocks, respectively, 28 ($p < .01$), 33 ($p < .001$), and 32 ($p < .01$) participants followed the "convergence" pattern seen in Figure 2b for hard, buzz trials.

Confidence Ratings: Control Group

As Figure 2d shows, stimulus difficulty and the perceptible buzz affected confidence in the control group, but there was no interaction between these variables. Compared with difficult items, easy items elicited 0.88 higher confidence in hits, $F(1, 37) = 25.6$, $\eta_p^2 = .35$, and 0.51 higher confidence in false alarms, $F(1, 37) = 9.3$, $\eta_p^2 = .14$. The buzz reduced confidence in hits by 0.97, $F(1, 37) = 17.4$, $\eta_p^2 = .22$, and confidence in false alarms by 0.52, $F(1, 37) = 8.9$, $\eta_p^2 = .13$. To verify that overall patterns differed across the two groups, we combined the data: The Difficulty × Buzz × Condition interaction was again reliable, $F(2, 74) = 49.3$, $\eta_p^2 = .38$.

DISCUSSION

In neuropsychology, two complementary syndromes are prosopagnosia and the Capgras delusion (Ellis & Lewis, 2001). In *prosopagnosia*, people cannot recognize faces. Nevertheless, their galvanic skin responses suggest an emotional response to familiar people. In the *Capgras delusion*, people become convinced that very familiar people (usually spouses) have been replaced by impostors. They "recognize" familiar faces, but lack covert emotional responses. Together, these syndromes underscore a two-stage recognition process with separate production and evaluation of mental states. The present results also suggest such dual processes, albeit less dramatically.

We investigated whether a subliminal somatic cue (posterior buzz), unrelated to test items, would affect recognition memory and confidence. As anticipated, the buzz increased participants' likelihood of responding "old," both correctly and incorrectly. Notably, this effect occurred only for the subjectively harder stimuli. Given difficulty in recollection, people rely on "gut feelings" (Jacoby & Dallas, 1981), which are susceptible to manipulations of fluency or arousal. In the present case, without awareness of the buzz, people made the only reasonable attribution: Its meager sensory activity was credited to stimulus familiarity. Conversely, participants who experienced an obvious buzz had no illusion of familiarity.

With respect to SCAPE, the confidence results were especially interesting. When people committed false alarms, the subliminal buzz elicited relatively high confidence. For hits, the subliminal buzz had the opposite effect, reducing confidence. According to the discrepancy-attribution hypothesis, the same signal can produce such disparate effects, because of predictable changes in expectations across trials. In SCAPE, feelings of familiarity arise when evaluation detects some change in production; those feelings elicit different interpretations depending on context (Whittlesea & Williams, 2001). When items are new, extrinsically heightened familiarity is naturally attributed to prior experience, falling just short of recollection. Hence, people tend to respond “old” with relatively high confidence. With little else to go on, familiarity is reassuring. Conversely, when items are old and production is fluent, the artificial familiarity signal introduces a shadow of doubt. Thus, people still tend to respond “old,” but their confidence declines.[3] Taken together, these results support the SCAPE theory of recognition and familiarity.

Acknowledgments—This work was supported by Grant R01-DC04535 from the National Institute on Deafness and Other Communication Disorders. We thank Tamiko Azuma and Jim Craig for discussions, Robert Azuma and Ethan Chamberlain for help, and Susan Somerville for her chair.

REFERENCES

Cheesman, D.J., & Merikle, P.M. (1986). Distinguishing conscious from unconscious perceptual processes. *Canadian Journal of Psychology*, *20*, 84–100.

Coltheart, M. (1981). The MRC psycholinguistic database. *Quarterly Journal of Experimental Psychology*, *33A*, 497–505.

Ellis, H.D., & Lewis, M.B. (2001). Capgras delusion: A window on face recognition. *Trends in Cognitive Sciences*, *5*, 149–156.

Gilhooly, K.J., & Logie, R.H. (1980). Age of acquisition, imagery, concreteness, familiarity and ambiguity measures for 1944 words. *Behavior Research Methods and Instrumentation*, *12*, 395–427.

Homa, D., & Vierra, C. (1988). Long-term memory for pictures under conditions of thematically related foils. *Memory & Cognition*, *16*, 411–421.

Jacoby, L.L., & Dallas, M. (1981). On the relationship between autobiographical memory and perceptual learning. *Journal of Experimental Psychology: General*, *110*, 306–340.

Jacoby, L.L., & Whitehouse, K. (1989). An illusion of memory: False recognition influenced by unconscious perception. *Journal of Experimental Psychology: General*, *118*, 126–135.

Leboe, J.P., & Whittlesea, B.W.A. (2002). The inferential basis of familiarity and recall: Evidence for a common underlying process. *Journal of Memory and Language*, *46*, 804–829.

Merikle, P., Smilek, D., & Eastwood, J.D. (2001). Perception without awareness: Perspectives from cognitive psychology. *Cognition*, *79*, 115–134.

Neisser, U. (1967). *Cognitive psychology*. New York: Appleton-Century-Crofts.

Schachter, S., & Singer, J.E. (1962). Cognitive, social and physiological determinants of emotional state. *Psychological Review*, *69*, 379–399.

Tulving, E., & Thompson, D. (1973). Encoding specificity and retrieval processes in episodic memory. *Psychological Review*, *80*, 352–373.

Whittlesea, B.W.A. (1997). Production, evaluation and preservation of experiences: Constructive processing in remembering and performance tasks. In D. Medin (Ed.), *The psychology of learning and motivation Vol. 37* (pp. 221–264). New York: Academic Press.

Whittlesea, B.W.A., & Leboe, J. (2000). The heuristic basis of remembering and classification: Fluency, generation and resemblance. *Journal of Experimental Psychology: General*, *129*, 84–106.

Whittlesea, B.W.A., & Williams, L.D. (1998). Why do strangers feel familiar, but friends don’t? A discrepancy-attribution account of feelings of familiarity. *Acta Psychologica*, *98*, 41–65.

Whittlesea, B.W.A., & Williams, L.D. (2001). The discrepancy-attribution hypothesis: I. The heuristic basis of feelings of familiarity. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *27*, 3–13.

(Received 6/25/04; Revision accepted 10/12/04)

[3]We examined this interpretation further in a pilot experiment, with the subliminal buzz paired with *only* new or old items ($n = 5$ per condition). Preliminary results were consistent with SCAPE: A buzz paired with new items increased false alarms; a buzz paired with old items decreased hits slightly.