Available online at www.sciencedirect.com
ScienceDirect
Journal of Consumer Psychology 21 (2011) 354 – 361
Journal of CONSUMER PSYCHOLOGY

Short Article

Is scent-enhanced memory immune to retroactive interference?

Maureen Morrin [a,*], Aradhna Krishna [b], May O. Lwin [c]

[a] Rutgers University, 227 Penn St., Camden, NJ 08102, USA
[b] Ross School of Business, University of Michigan, 701 Tappan Street, Ann Arbor, MI 48109–1234, USA
[c] Wee Kim Wee School of Communication and Information, Nanyang Technological University, 31 Nanyang Link, Singapore 637718, Singapore

Received 7 April 2010; revised 9 February 2011; accepted 22 February 2011
Available online 21 March 2011

Abstract

Research shows that scent enhances memory for associated information. Current debate centers around scent's immunity to "retroactive interference," i.e., reduced memory for earlier-learned information after exposure to additional, subsequently-learned information. This paper demonstrates that scent-enhanced memory is indeed prone to retroactive interference, but that some of the information lost is restored using a scent-based retrieval cue. Two process explanations for interference effects are proposed, with the evidence providing more support for an inhibition rather than a response competition explanation. The results enhance our understanding of the encoding and retrieval of olfactory information from long-term memory, and reasons why interference occurs.

Keywords: Scent; Memory; Retroactive interference; Olfactory uniqueness

As consumers, we are exposed to a plethora of product information every day. We wake up with the radio playing advertising jingles, drive to work and see billboards along the way, log onto our computers and see banner ads, and then watch television in the evening with exposure to even more ads. Similarly, when we go shopping we are surrounded by literally thousands of products on the shelves. Given the sheer number and the variety of stimuli to which we are exposed, it is not surprising that we remember only a small proportion of these over time.

Acknowledging the glut of information that consumers face, manufacturers do everything in their power to increase recall of information about their brands. For instance, marketers send the same advertising message using different media, they utilize ad repetition, and they incorporate the elements of surprise or novelty to make the message more memorable. Recently, marketers have taken to adopting the use of "signature scents" (Davies, Kooijman, & Ward, 2003) to increase recall for their products and services. These proprietary scent combinations have been adopted by several hotels, for example—Westin has white tea with geranium and freesia. Westin hotel guests can buy toiletries that contain the signature scents to take home with them, and Westin gives gifts of scented pens to guests. Presumably, these scents help to cut through the clutter to aid guests in remembering features of the hotel that they enjoyed, so that they return to it.

The use of scent to increase consumer memory has considerable scientific basis. For instance, Krishna, Lwin, and Morrin (2010) have shown that product scent increases memory for associated information. While scent may help cut through the information clutter and help enhance memory, does this enhanced memory survive interference from future information that the consumer is exposed to?

There is a debate in psychology about whether or not scent is immune to "retroactive interference," i.e., whether there is reduced memory for scent-associated information after exposure to additional scent-associated information. Moreover, the underlying process for retroactive interference effects has not been fully explored by psychologists. Likewise in marketing, research on retroactive interference effects—when exposure to

* Corresponding author.
E-mail addresses: mmorrin@rutgers.edu (M. Morrin), aradhna@umich.edu (A. Krishna), tmaylwin@ntu.edu.sg (M.O. Lwin).

1057-7408/$ - see front matter © 2011 Society for Consumer Psychology. Published by Elsevier Inc. All rights reserved.
doi:10.1016/j.jcps.2011.02.008

information concerning a second brand decreases recall for the first—has not focused on the underlying process (Burke & Srull, 1988; Jewell & Unnava, 2003; Keller, 1987; Kumar & Krishnan, 2004; Webb & Ray, 1979).

The long-term memory study presented here shows that scent-enhanced recall is indeed reduced in the face of additional information exposure (i.e., it is *not* immune to retroactive interference). However, it is also shown that a scent-aid restores some of the lost information and the memory advantage afforded by scent. Two processes are proposed that could result in retroactive interference, with the results providing initial evidence that the underlying process is one of inhibition rather than response competition (i.e., intrusion/confusion in memory). These results enhance our understanding of how consumers encode and retrieve olfactory information from long-term memory, and of why interference effects may occur.

Prior research on scent and memory

Prior research has shown that humans exhibit very strong memory for scents themselves (Buck & Axel, 1991), as well as for information that has come to be associated with scents (Morrin & Ratneshwar, 2003; Krishna et al., 2010; Lwin, Morrin, & Krishna, 2010). Superior olfactory memory may be due to the hippocampal resource advantage that olfactory encoding enjoys whereby olfaction has closer physical and neural proximity with the hippocampus, compared to other senses (Herz & Engen, 1996; Wixted, 2004). Because of this superior encoding for scent and associated information, long-term memory for scent-associated information is especially powerful and long-lasting (Krishna et al., 2010), and can even increase the memory-boosting effect of pictures on verbal memory (Lwin et al., 2010).

However, what happens to this enhanced brand memory if the consumer is subsequently exposed to other competing scented brands within the same product category? Is the memory-enhancement due to scent attenuated, or are the scent-based associations impervious to interference? This is the core issue addressed in the present research.

That information subsequently learned causes interference and forgetting is an important facet of most memory models (e.g., Raaijmakers & Shiffrin, 1981). Associative network models posit that information is encoded in long-term memory as a network of linkages between concept nodes. While information may be permanently encoded in long-term memory, only a portion of the encoded information might be retrievable, depending on available memory cues. At retrieval, memory cues activate corresponding concept nodes and thereby associated information in the network of linkages. With exposure to multiple similar stimuli over time, there are a larger number of links from the same concept nodes, which may decrease the retrieval likelihood of any single item of associated information—evident in retroactive interference effects.

Psychologists assumed for a long time that olfactory memory is not subject to these types of interference effects, but recent evidence has contested that belief, and has resulted in a debate. These studies are discussed next.

Studies supporting scent's immunity to interference

Odor-recognition studies

In odor recognition studies, researchers measure memory for scent itself, as opposed to memory for scent-associated information. Participants are exposed to a series of odors, and are later exposed to another set of odors that contain both those that were smelled before and those that were not, in a forced recognition paradigm. Thus, individuals' ability to recognize scents they have experienced before is measured over time. For example, studies from the 1960s and 1970s show that whereas forgetting rates for stimuli such as words and pictures exhibit a logarithmic rate of decline (Shepard, 1967), the forgetting rates for odors exhibit only minimal decay (Engen & Ross, 1973; Lawless & Cain, 1975).

Study on memory for scent-associated information

Another study (Lawless & Engen, 1977) supports the immunity of scent-associated information to retroactive interference. Lawless and Engen exposed participants to twelve different scents and twelve different picture postcard-like scenes from foreign countries. While sniffing a scent from a test tube, participants were instructed to look at one of twelve pictures on a display board and to memorize the association between the scent and the picture (time 1). Two days later (at time 2), one group of participants (n=10) was exposed to the same twelve scents, but they were paired with different pictures (within the same set). Two weeks later (at time 3), given the original scents and all the pictures, this group's recognition accuracy for the first set of scent-picture pairings did not decline, and was as accurate as that of the control group, suggesting little or no retroactive interference. A more recent study (Zucco, 2003, study 2) partially replicated these results.

Study contesting scent's immunity to interference

In the early odor-recognition studies, there were no attempts to explicitly introduce interference as part of the study designs. They were basically tests of memory-decay for scent over time. Walk and Johns (1984), in their attempt to test the notion that scent memory is immune to interference, explicitly introduced interference into their study design. They exposed participants to two food scents; then presented them (or not—control) with other potentially interfering information (a third scent, the name of a third scent), or helpful information (the name of one of the original two scents); and finally gave them four scents of which one was the original scent that needed to be recognized. The correct recognition rate was significantly higher in the helpful condition (M=.83) versus the control (M=.56) or the two interference cells (M=.37, M=.49). The authors concluded that odor recognition memory can indeed be interfered with (see also Koster, Degel, & Piper, 2002; Olsson, Lundgren, Soares, & Johansson, 2009).

Debate on whether scent memory is immune to interference

As we can see, there are mixed results regarding whether or not olfactory memory is resistant to retroactive interference

effects—there is much support for scent-memory being immune to retroactive interference along with some contradictory evidence. If one examines these prior findings, one notices some commonalities among them—all of them focus on recognition (of scent or of information associated with a scent) but not on recall; second, all of them focus on scent-aided (rather than unaided) memory retrieval. Third, they do not focus on the process whereby retroactive interference occurs.

Next we discuss two processes that could account for retroactive interference effects (if they are evident in this domain) followed by our study and the results.

Conceptual framework

Two process accounts for retroactive interference

Prior research indicates that forgetting is not merely due to the amount of time that has elapsed since exposure to a stimulus (Jenkins & Dallenbach, 1924), but rather is due primarily to retroactive interference—exposure to other stimuli and the additional learning that occurs (e.g., McGeoch, 1942; Melton & Irwin, 1940; Underwood, 1957; Wixted, 2004). When instead, previously learned information interferes with the ability to recall later learned information, proactive inhibition is said to have occurred (Wixted, 2004); but today most researchers discount its possibility given much disconfirming evidence (Wixted, 2004). Thus, our focus here is primarily on the effects of retroactive interference.

The basic idea of retroactive interference is that once information is entered into long-term memory, other memory traces that are subsequently created due to exposure to additional, similar information, somehow interfere with the ability to remember the original set of memory associations. This phenomenon has been substantiated in the domain of consumer behavior. Webb and Ray (1979), for example, reported significant negative clutter effects (number of advertisements seen) on ad attention and recall of any specific brand. Other consumer behavior research has also shown that exposure to information concerning a second brand can decrease recall for the first, demonstrating typical retroactive interference effects (Burke & Srull, 1988; Jewell & Unnava, 2003; Keller, 1987; Kumar & Krishnan, 2004).

A decline in retrieval ability due to retroactive interference could be attributed to at least one of two different processes (Martindale, 1991): inhibition and/or response competition. Both of these theories suggest that forgetting occurs because interpolated information interferes with previously learned information (i.e., the definition of retroactive interference). They differ, however, in the precise nature of the underlying process.

Inhibition

The response inhibition explanation suggests that if consumers are first exposed to stimulus A and then to a similar stimulus B, the interpolated learning inhibits retrieval of stimulus A, i.e., exposure to a similar stimulus B serves to inhibit (i.e., temporarily reduce the accessibility of) stimulus A. However, with the provision of adequate retrieval cues, the first-list items or original learning should be "released" from inhibition and thus become accessible and retrievable, if inhibition is indeed the underlying process.

Response competition (intrusion or confusion in memory)

The response competition explanation (McGeoch, 1942) is based on the notion that if one is exposed to stimulus A and then to a similar stimulus B, then individuals can remember both stimuli A and B; however, they cannot remember which piece of information belongs to which stimulus, and in this sense the two responses compete with each other. In this case, individuals do not forget either of the stimulus-information associations, they are simply confused about which goes with which—so sometimes they will give a B response when an A response is called for (and vice versa). Some research suggests that response competition is a major driver of retroactive interference effects (Bower, Thompson-Schill, & Tulving, 1994). Response competition theory has a clear implication, namely, that most retrieval errors for stimulus A will consist of *intrusions* from information about stimulus B (Martindale, 1991), or vice versa.

While some researchers have argued that response competition is the single most important factor underlying retroactive interference (Bower et al., 1994), prior research has also shown much support for scent "aided" memory's immunity to retroactive interference, indicating that retroactive interference effects may be due to the inhibition explanation. But, it is not as if one of these two processes prevents the other from occurring—both inhibition and response competition can occur in conjunction, creating retroactive interference and reducing recall. As such, we propose that:

H1. Scenting a product will enhance both unaided and aided consumer memory (replicating prior research).

H2. Exposure to another scented brand in the same product category (i.e., competitive exposure) will produce retroactive interference effects, as measured by a reduction in unaided recall.

H3. Providing a scent-based cue at the time of retrieval will restore some of the information "lost" to retroactive interference (providing evidence to support an inhibition process).

H4. When there is competitive interference, some attributes belonging to Brand A [B] may be mistakenly attributed to Brand B [A] (i.e., intrusions), so that brand recall and brand intrusions will be negatively correlated (providing evidence to support a response competition process).

Method

Subjects, design, and stimuli

One hundred and eight undergraduate students took part in this study in return for course credit and a small cash payment. We employed a 2 (product scent: yes, no) × 2 (competitive exposure: yes, no) full factorial design. Participants were

randomly assigned to one of these four cells. The study entailed three separate participant interactions separated by 2 weeks each, i.e., requiring a 4-week engagement on the part of participants—exposure to the first stimulus was followed by a 2-week delay at which time participants in the interference conditions were exposed to another (potentially interfering) stimulus. After another 2 weeks, all participants' memory was tested.

All participants were exposed to a moisturizer product at time 1—a product that either was or was not scented. At time 2, participants in the competitive exposure cells were exposed to another moisturizer product—this product either was or was not scented, in accord with the scent condition experienced at time 1. Those in the no interference condition did not return at time 2. When the interfering brand encountered at time 2 was scented, it contained either the same scent as the brand encountered at time one or a different scent. There were no effects as a function of scent type—same or different—encountered at time 2, so we collapsed across this variable in the analyses. Hereafter, we refer to this cell as the scented competitive exposure cell.

Two pretests were conducted to choose equally liked and equally appropriate hypothetical brand names and scents for the two moisturizers used for the target and competitive exposure products. Based on these pretests, we chose Pamplona as the brand name for time 1, and Ceville as brand name for time 2 (for those in the competitive exposure cells). Orange blossom was chosen as the product scent for time 1 (among those in the scented cell at time 1) and either orange blossom or sandalwood was used at time 2 (for those in the scented competitive exposure cell). To create the moisturizer stimuli, a generic brand of unscented white moisturizer was used—this was the control. For all conditions, we poured 10 ml of moisturizer into a small transparent airtight plastic container, with a brand label on the side (Pamplona or Ceville). In the scented conditions, two drops of essential oil were added to the moisturizer. Each participant received a separate, new (unopened) container.

Procedure

The experiment took place in a large and well-ventilated room, with each subject allocated a minimum 6 ft by 6 ft space. All participants at time 1 were instructed: "A new line of body moisturizers is currently in its final stages of development. However, before the product is launched officially onto the market, we would like you to take a look at its list of attributes and consider them carefully. A sample of the body moisturizer is provided as well. Using the provided sample, you may view, feel, and smell the body moisturizer in order to better evaluate it."

Participants examined the Pamplona moisturizer product (i.e., Brand A) and a print advertisement containing several copy points about the product (see Appendix A). They then were asked to: "Please write down everything you thought about while examining this product and reading its advertisement".

Two weeks later, at time 2, participants in the competitive exposure conditions were exposed to another moisturizer, Ceville (i.e., Brand B; either with or without a scent) and a print ad containing several copy points about this product (see Appendix A). Subjects followed the same procedure as at time 1. Those in the no competitive exposure conditions did not report back at time 2.

Two weeks after time 2, at time 3, all participants returned for a surprise recall task, in which they were asked to write down the brand name(s) of the moisturizer(s) they had examined, as well as everything else they could remember about both brands. They were asked about Brand A first (without knowing that they would subsequently be asked about Brand B). A separate sheet of paper was provided for each product for those who had been exposed to more than one brand. This was the measure of unaided recall. To measure aided recall, participants were then provided with a piece of paper in a bottle. For those in the scented [unscented] conditions, the paper was infused with the scent(s) previously encountered [or was unscented]. They were instructed to take at most two breaths from a bottle provided to them and then to write down any *additional* information they could recall about the moisturizer product.

A major reason to measure both aided and unaided recall is to test whether inhibition drives retroactive interference. By providing participants with a scented retrieval cue associated with Brand A we can see if previously inhibited information about Brand A (information not accessible without the scent-retrieval cue) is released from inhibition and made accessible. To test for response competition we check for the incidence of intrusions—(incorrectly) recalling an attribute of one brand when trying to remember attributes of another brand.

Results

Variables and tests used

To determine whether the memory-enhancing effect of scent is immune to retroactive interference, we employ two types of comparisons, one that tests for an absolute effect of interference (scented product with versus without competitive exposure) and the other for a relative one (scented versus unscented product—in the context of competitive exposure). Fig. 1 illustrates these tests.

Before we do either tests, we need to verify that more information is remembered about a scented versus unscented product (H1)—this serves as a replication of past work on scent and memory and is given by the difference between recall for a scented versus unscented product in the absence of competitive exposure (i.e., no exposure to Brand B). For the absolute interference effect test, we look at the difference between recall for a scented product when there is competitive exposure (i.e., to Brand B) versus not. For the relative interference effect test, we see whether, in the context of competitive exposure, recall is still better when the product is scented rather than unscented. Both the absolute and relative interference effect tests relate to H2. For testing H3, we see if providing a scent-based retrieval cue restores some of the information "lost" to retroactive interference. Finally, we conduct additional tests to assess

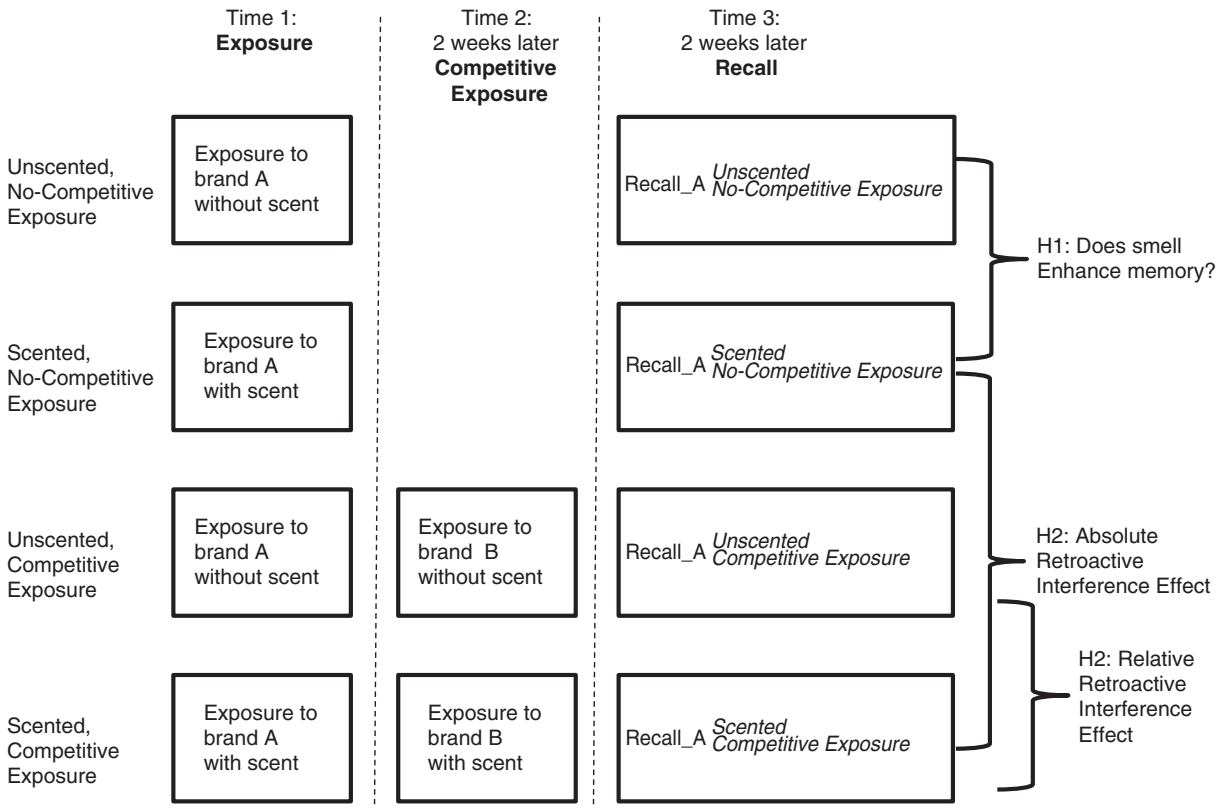

Fig. 1. Tests for enhanced memory and retroactive interference.

whether response competition drives retroactive interference through an analysis of intrusions (H4).

We analyzed both unaided and aided recall of the first brand encountered. We tabulated whether the brand name was recalled (correctly or nearly correctly spelled) as well as the number of brand attributes listed that reflected those appearing in the print ads (e.g., available in handy tube sizes, contains aloe vera, etc.). Unaided recall is the sum of correct items freely recalled without the aid of a retrieval cue. Aided recall is an incremental measure over and above unaided recall. Mean results are provided in Table 1 and Fig. 2. Gender was not significant ($p > 0.2$) and is not discussed further.

Unaided recall

We conducted an ANOVA on unaided recall for Brand A as a function of scent (yes, no) and competitive exposure (yes, no; $F(3, 104) = 3.84$, $p < .05$, $\eta^2 = .10$). Scent ($F(1, 104) = 5.83$, $p < .05$, $\eta^2 = .05$) and the interaction between scent and competitive exposure ($F(1, 104) = 5.94$, $p < .05$, $\eta^2 = .05$) were significant. Following up on the interaction effect, we first looked at means in the no competitive exposure condition for the scented versus unscented cells. Mean comparisons show that, in the absence of competitive exposure, a scented product's attributes are better recalled than those of an unscented product ($M = 2.18$ versus 1.11, $p < .01$). This result demonstrates the basic memory-enhancing effect of product scenting in support of H1 and replicating results reported in prior research.

Testing for retroactive interference, we find that in the scented condition, unaided recall is significantly lower for Brand A in the context of competitive exposure ($M = 1.40$ vs. 2.18, $p < .01$), supporting H2 for the absolute difference interference test. This result provides clear evidence of retroactive interference. In fact, unaided recall in the scented competitive exposure condition ($M = 1.40$) was no better than the level of unaided recall achieved in either of the unscented conditions ($M = 1.11$ and 1.40, $p > .35$, see Fig. 2). In effect, competitive exposure eliminated all of the memory advantage provided by product scenting, on an unaided recall basis.

The relative interference test shows that the difference between the two unscented cells is not significant ($p > .35$), whereas the difference between the two scented cells is ($p < .01$), demonstrating that there is more to lose due to competitive exposure when the product is scented. Thus, it appears that scenting a product does not protect it from retroactive interference in terms of consumers' performance on unaided recall tasks.

Aided recall

We conducted a similar ANOVA on aided recall for Brand A as a function of scent (yes/no) and competitive interference (yes/no), and found that both scent ($F(1, 104) = 428.8$, $p < .0001$, $\eta^2 = .29$) and competitive exposure ($F(1, 104) = 6.92$, $p < .01$, $\eta^2 = .06$) were significant. Mean comparisons show that when participants were provided with the scented retrieval cue, they incrementally recalled a larger number of

Table 1
Mean items recalled and mean number of intrusions by condition for Brand A (Pamplona).

	No competitive exposure cells		Competitive exposure cells	
	Unscented moisturizer: Pamplona brand (a) n=18	Scented moisturizer: Pamplona brand (b) n=22	Unscented moisturizer: Ceville brand (c) n=25	Scented moisturizer: Ceville brand (d) n=43
Unaided recall of A	1.11 (.27)	2.18 (.23)[a]	1.40 (.22)[b]	1.40 (.17)[b]
Aided recall of A	0.18 (.14)	1.15 (.13)[a]	0.00 (.12)[b]	0.65 (.09)[a,b,c]
Total	1.29 (.32)	3.32 (.29)[a]	1.40 (.28)[b]	2.05 (.27)[a,b]
Unaided Intrusions by B	0.00	0.00	0.00 (.07)	0.21 (.05)[c]
Aided intrusions by B	0.00	0.00	0.00 (.08)	0.12 (.06)
Total	0.00	0.00	0.00 (.10)	0.33 (.12)[c]
Unaided intrusions by A	0.00	0.00	0.04 (.09)	0.30 (.07)[c]
Aided intrusions by A	0.00	0.00	0.00 (.07)	0.16 (.05)
Total	0.00	0.00	0.04 (.13)	0.46 (.10)[c]

Reading from left to right in a row, a mean is significantly different from a mean to its left at $p<.05$ as denoted by a superscript indicating the column where the different mean is located (i.e., column a, b, or c). Standard errors are in parentheses. An intrusion is an instance where the respondent recalled an item of information associated with one brand (e.g., Brand B) when attempting to recall information about another brand (e.g., Brand A). The theoretical range for both mean recall and number of intrusions is 0 to 7.

items of information about Brand A if the brand had been scented versus not scented ($M=0.89$ vs. $M=0.08$, $p<.01$). This result provides additional support for H1 regarding the memory-enhancing effect of scent. Additionally, providing the scented retrieval cue produced more incremental recall when there was no competitive exposure, compared to when there was ($M=0.65$ vs. $M=0.33$, $p<.01$). This result provides additional support for H2, regarding the interfering effect of competitive exposure.

We also find initial evidence that the retroactive interference effect seen in unaided recall may partly be due to an inhibitory process. Some of the information "lost" due to retroactive interference is restored when the scent retrieval cue is provided, supporting H3. We find that providing the retrieval cue restores about 0.65 items of information in the scented competitive exposure condition, which is more than that in the unscented competitive exposure cell ($M=0.00$, $p<.01$). This result demonstrates that, if provided with an adequate retrieval cue, in this case, the product's scent, some of the information that was retroactively interfered with can later be made accessible and retrieved—suggesting that such information is available, if not always accessible, from long-term memory.

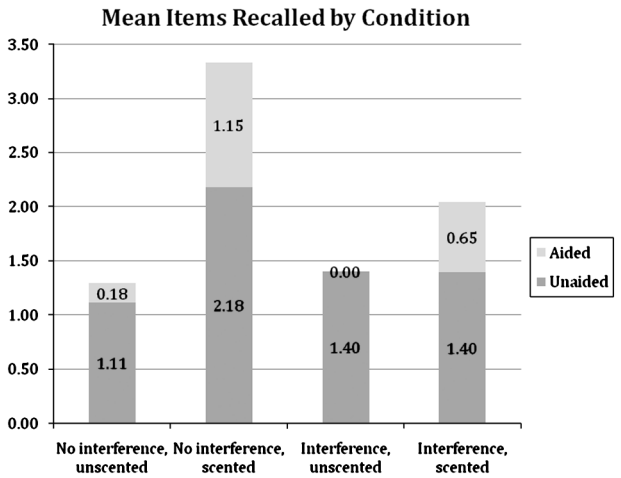

Fig. 2. Mean items recalled by condition.

While we have initial evidence for inhibition occurring, we need to further explore the possible role of confusion (i.e., response competition measured via intrusions) in impairing the recall of information for Brand A in a competitive context. This is discussed next.

Intrusions

Per H4, if intrusions (an inability to correctly pair brand names with their corresponding attributes) are driving the reduction in unaided recall for Brand A, then there should be a significant and negative correlation between Brand A recall and either the number of intrusions by Brand B (i.e., mistakenly recalling Brand B information when trying to recall Brand A information) or by Brand A (i.e., mistakenly recalling Brand A information when trying to recall Brand B information). That is, if retroactive interference is caused by memory for attributes for Brand A "shifting" to Brand B, or vice versa (for a crowding out effect), then a decline in the correct recall of Brand A should be associated with an increase in such shifts (i.e., negative correlations). As one would expect, the number of intrusions in the scented no-competitive interference cell is 0, whereas in the scented competitive interference cells they are greater than 0 (0.33 by B and .46 by A, $p<.05$; see Table 1). Among the participants exposed to two scented moisturizers, intrusions by Brand B are not significantly correlated with unaided ($r=-.11$, $p>.45$) or aided ($r=.11$, $p>.45$) recall for Brand A. This result does not support H4—it does not appear that interference with Brand A recall is driven by intrusions from Brand B attributes.

We also examine whether Brand A attributes are misattributed to Brand B, and whether this could be driving down Brand A's recall. Among those exposed to the two scented moisturizers, we find that intrusions by Brand A (i.e.,

mistakenly recalling brand A information when trying to recall brand B information) are significantly and positively correlated with both unaided ($r=.43$. $p<.01$) and aided ($r=.49$, $p<.001$) recall for Brand B. Note, however, that this result does not provide evidence of response competition (H4), since the direction of the correlation is positive rather than negative (that is, more intrusions of A are associated with *higher* recall of A). Thus, this analysis does not provide evidence for a response competition explanation of retroactive interference. Instead, it appears from this analysis that people who recall more about Brand A also misattribute additional attributes of A to Brand B.

Thus, from these initial analyses we find some initial support for inhibition as a driver of retroactive interference effects, but not for response competition. However, these analyses are very preliminary and additional research needs to be done to explore these processes in greater detail.

General discussion

While there is considerable anecdotal evidence as well as research results supporting the persistence of scent-related memories over time, there is disagreement over whether or not olfactory memory is resistant to interference. We shed light on this issue by exploring the effect of scent on consumer memory over time in a competitive market context. We also explore the underlying process of how competitive exposure might decrease scent-enhanced memory by measuring both unaided and scent cue-aided recall as well as memory intrusions.

What we find is that scent is indeed an effective long-term memory enhancer, but this is not due to the fact that scent-associated information is immune to later exposure to similar information—that is, it is not due to some special immunity from retroactive interference. We clearly demonstrate that in the context of competitive exposure, scented products no longer exhibit superior memory—unless a scented retrieval cue is provided to aid memory—in which case scent-aided recall is superior to unscented memory, even with competitive exposure in the former case. Our results suggest that the memory-enhancing effect of scent is a function of enhanced olfactory-based encoding that can be temporarily inhibited by exposure to competing information; but at least some of this lost information may be subject to restoration given appropriate cueing.

We find that some of the "lost" information was re-instituted with re-exposure to a scented retrieval cue. This result shows how the incremental information stored at encoding due to the presence of scent continues to be available, even in the context of scent-based competitive exposure, and can later be made accessible with adequate (i.e., original scent-based) retrieval cues. Additional tests show that although scented brands cause more confusion among consumers in terms of remembering which attributes belong to which brands, confusion (or response competition) does not appear to explain the reduction in memory for the first scented brand encountered. Instead, the analyses provide some support for inhibition (as evidenced by the release from inhibition evident in the scent aided recall results) as the driver of the observed interference effects. However, our findings regarding the process accounts are preliminary and need further research before one can conclusively say which process has a greater reducing effect on recall in a competitive context. Additionally, other processes can also be explored such as attention, lingering time, whether humans process scent one at a time in a linear fashion, etc.

While we did not focus on proactive inhibition (where information learned earlier interferes with information learned later), we also tested for such effects. As a measure of proactive inhibition, we compared the *proportion* of attributes recalled for Brand A versus that for Brand B by condition in those groups exposed to competitive information—we found no significant differences. However, future research should also explore the processes associated with proactive inhibition.

We acknowledge that the current set of results are based on a single study and need to be replicated in other settings before hard conclusions can be made about the superiority of olfactory memory processes. Note that in our study, we did not find evidence for retroactive interference in the unscented condition (see columns a versus c of Table 1)—this needs further research. In our no-competitive-interference conditions, participants came to the laboratory just once, whereas those in the competitive interference conditions came to the laboratory twice. Our results should be replicated with a design that brings participants in the control conditions back to the laboratory as well.

Although the type of scent encountered at time 2 in this study did not impact the degree of interference, future research should investigate this issue—that is, the degree of scent similarity and extent of interference effects. Another avenue for further research is to replicate our experiment with the interference occurring very soon after exposure to the first product, and seeing if even aided recall exhibits interference effects. Finally, retroactive interference is also evident in other (non-olfactory) domains (e.g., Burke & Srull, 1988), but the reasons for this have not been explored. Future research could test for inhibition or intrusion within these other domains.

Appendix A

Brand attribute information given in print ads used in study 1 (time 1, time 2).

Pamplona

- Comes in handy tubes of different sizes
- Is a non greasy cream that absorbs easily into the skin
- Leaves your skin feeling soft and healthy
- Is formulated with Aloe Vera and other natural plant extracts
- Contains Vitamin E to fight aging
- Is great for people whose skin peel often

Ceville

- Eliminates discoloration of the skin
- Contains sunscreens to give great protection against the sun
- Is suitable for all skin types
- Is made entirely with Swiss Pride
- Contains Vitamin C
- Moisturizes skin

Examples of Pamplona recall "hits": "Has vitamin E," "Different package sizes."

Example of Pamplona recall "misses": "It feels expensive too," "The ads are also quite attractive".

References

Bower, G. H., Thompson-Schill, R., & Tulving, E. (1994). Reducing retroactive interference: an interference analysis. *Journal of Experimental Psychology. Learning, Memory, and Cognition*, *20*(1), 51−66.

Buck, L., & Axel, R. (1991). A novel multigene family may encode odorant receptors: a molecular basis for odor recognition. *Cell*, *65*(1), 175−187.

Burke, R., & Srull, T. (1988). Competitive interference and consumer memory for advertising. *Journal of Consumer Research*, *15*(1), 55−68.

Davies, B. J., Kooijman, D., & Ward, P. (2003). The sweet smell of success: Olfaction in retailing. *Journal of Marketing Management*, *19*, 611−627.

Engen, T., & Ross, B. M. (1973). Long-term memory of odors with and without verbal descriptions. *Journal of Experimental Psychology*, *100*, 221−227.

Herz, R. S., & Engen, T. (1996). Odor memory: Review and analysis. *Psychonomic Bulletin & Review*, *3*(3), 300−313.

Jenkins, J. G., & Dallenbach, K. M. (1924). Oblivescence during sleep and waking. *The American Journal of Psychology*, *35*, 605−612.

Jewell, R., & Unnava, H. (2003). When competitive interference can be beneficial. *Journal of Consumer Research*, *30*(2), 283−291.

Keller, K. (1987). Memory factors in advertising: the effect of advertising retrieval cues on brand evaluations. *Journal of Consumer Research*, *14*(3), 316−333.

Koster, E. P., Degel, J., & Piper, D. (2002). Proactive and retroactive interference in implicit odor memory. *Chemical Senses*, *27*, 191−206.

Krishna, A., Lwin, M. O., & Morrin, M. (2010). Product scent and memory. *Journal of Consumer Research*, *37*(1), 57−67.

Kumar, A., & Krishnan, S. (2004). Memory interference in advertising: a replication and extension. *Journal of Consumer Research*, *30*(4), 602−611.

Lawless, H., & Cain, W. (1975). Recognition memory for odors. *Chemical Senses*, *1*, 331−337.

Lawless, H., & Engen, T. (1977). Associations to odors: Interference, mnemonics, and verbal learning. *Journal of Experimental Psychology: Human Learning and Memory*, *3*(1), 52−59.

Lwin, M., Morrin, M., & Krishna, A. (2010). Exploring the superadditive effects of scent and pictures on verbal recall: an extension of dual coding theory. *Journal of Consumer Psychology*, *20*(3), 317−326.

Martindale, C. (1991). *Cognitive psychology: a neural-network approach.* Pacific Grove, CA: Brooks/Cole Publishing Co.

Melton, A. W., & Irwin, J. M. (1940). The influence of degree of interpolated learning on retroactive inhibition and the overt transfer of specific responses. *The American Journal of Psychology*, *53*(2), 173−203.

McGeoch, J. A. (1942). *The psychology of human learning.* New York: Longmans.

Morrin, M., & Ratneshwar, S. (2003). Does it make sense to use scents to enhance brand memory? *Journal of Marketing Research*, *40*(1), 10−25.

Olsson, M. J., Lundgren, E. B., Soares, S. C., & Johansson, M. (2009). Odor memory performance and memory awareness: a comparison to word memory across orienting tasks and retention intervals. *Chemical Perception*, *2*, 161−171.

Raaijmakers, J. G., & Shiffrin, R. M. (1981, March). Search of associative memory. *Psychological Review*, *88*, 93−134.

Shepard, R. N. (1967). Recognition memory for words, sentences and pictures. *Journal of Verbal Learning and Verbal Behavior*, *6*, 156−163.

Underwood, B. J. (1957). Interference and forgetting. *Psychological Review*, *64*, 49−60.

Walk, H. A., & Johns, E. E. (1984). Interference and facilitation in short-term memory for odors. *Perception & Psychophysics*, *36*(6), 508−514.

Webb, P. H., & Ray, M. L. (1979, June). Effects of TV clutter. *Journal of Advertising Research*, *19*, 7−12.

Wixted, J. T. (2004). The psychology and neuroscience of forgetting. *Annual Review of Psychology*, *55*, 235−269.

Zucco, G. M. (2003). Anomalies in cognition: Olfactory memory. *European Psychologist*, *8*(2), 77−86.