
Olfactory Conditioning of Positive Performance in Humans

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Abstract

Olfactory conditioning effects have been widely demonstrated in the animal literature but more seldom in human populations and rarely of consciously controlled human behaviors. Building upon previous work on negative performance, we report the first experimental evidence that odors can be used effectively in a classical conditioning paradigm to positively influence human behavior. In the present study, underachieving schoolchildren experienced unexpected success at a paper-and-pencil task in the presence of an ambient odor. When they later experienced the same odor again, performance on other tasks was superior to that of relevant control groups. These data substantially extend previous results on human olfactory classical conditioning and show that odors potentially can be used to exert positive influences on human behavior.

Key words: associative learning, classical conditioning, emotion, odor, self-esteem, success

Introduction

Olfactory conditioning has been widely demonstrated in the animal conditioning literature with results typically demonstrating that odors can function effectively as the conditioned stimulus (CS) in conditioning paradigms (e.g., Otto et al. 2000; Nizhnikov et al. 2002; Jones et al. 2005). Otto et al. (1997), for example, showed that the pairing of an odor with an aversive stimulus in rats results in their aversion to that particular odor. Indeed, studies have shown that this type of learning can occur in very young animals and with only a single pairing of an odor with an experience. Cheslock et al. (2000), for example, paired an odor with intraoral milk infusion for newborn rats, 3–5 h after birth. When this odor was subsequently re-presented, these weanlings showed sustained attachment to an empty nipple as if it still provided milk, whereas control weanlings showed little attachment.

The effectiveness of olfactory conditioning effects in the animal literature naturally inspires questions of whether such phenomena could also be shown in human populations. Recently, there has been renewed interest in laboratory demonstrations of olfactory conditioning in humans owing to the emergence of a number of phenomena, which have become linked to olfaction. The growing phenomena of sick building syndrome and multiple chemical sensitivity have been linked to some degree of olfactory conditioning (Magnavita 2001). Van den Bergh's (e.g., Van den Bergh et al. 1997, 1999) investigations have shown that the basis of multiple chemical sensitivity is likely to be a conditioned increase in olfactory

sensitivity to particular substances, triggering a range of negative somatic symptoms. Siegel (1999) has also proposed that such conditioning phenomena may be at the root of the "pre-treatment nausea" that many patients undergoing cancer chemotherapy treatment seem to experience. Incidences of posttraumatic stress disorder (PTSD) have also been linked to olfactory conditioning mechanisms where specific odors have vividly revived highly affective flashback memories in PTSD patients and olfactory conditioning has been proposed as a mechanism through which such associations could be treated (Vermetten and Bremner 2003). Indeed, olfactory stimuli are known to be particularly potent reminders of past experiences in non-PTSD individuals (Chu and Downes 2000, 2002). Olfactory conditioning has also emerged as an influence in areas as disparate as drug administration (Stockhorst et al. 1999) and cigarette smoking behavior (Lazev et al. 1999).

Nevertheless, olfactory conditioning has rarely been the subject of investigation in the human psychological literature because, in common with a vast majority of research areas in the behavioral sciences, research on human learning has largely ignored the olfactory modality. Nevertheless, the few studies that have focused on human olfaction and conditioning have met with some success. The first demonstration of olfactory conditioning in humans was by Kirk-Smith et al. (1983) who paired an ambient odor with an anxiety-inducing task. When the odor was presented again later on, participants reported experiencing elevated levels of anxiety,

and, furthermore, this effect was shown without participant's awareness of the odor. Comparable results have been shown by Marinkovic et al. (1989), who found that an odor–electric shock pairing resulted in higher skin-conductance responses (indicating physiological arousal) when the same odor was subsequently presented and by Moore and Murphy (1999) who presented an odor paired with a sharp puff of air directed at the participant's eye, causing a reflexive eyeblink. After a number of pairings, Moore and Murphy found that the presentation of the odor alone resulted in the eyeblink response.

The focus of the previous work on human populations has been on the conditioning of automatic and/or nonconscious behavior such as physiological or reflexive responses to stimuli, partly because tasks involving these types of response are simpler to engineer in a laboratory and partly because these types of responses are easier to measure. Nevertheless, of great interest and utility would be a methodology for investigating the olfactory conditioning of consciously controlled behavior. Such an approach was pioneered by Herz and colleagues (Epple and Herz 1999; Herz et al. 2004) whose novel studies clearly demonstrated that ambient odors could be conditioned to influence subsequent behavior in a negative manner. In these investigations, participants attempted to complete a simple task in the presence of an ambient odor, but the outcome of the task was rigged such that it was impossible to complete successfully. When participants were later presented with other tasks to complete in the presence of the same odor, performance proved to be weaker than comparable control groups, indicating that the odor had influenced their behavior. According to Herz, the basis of this phenomenon is the pairing of a CS odor with a reduced sense of motivation inspired by the negative outcome of the rigged task. She supported this notion by showing that subsequent presentation of the CS odor did not necessarily result in weakened overall performance (as indexed by task accuracy) but in a reduced motivation to complete task items (Herz et al. 2004).

This work inspires the question of whether olfactory stimuli could similarly be used to improve performance rather than weaken it. There is clear applied value in techniques which may boost human task performance and this methodology presents itself as a technique through which such an olfactory influence may be achieved. The aim of the present study therefore is to develop further this methodology and determine whether such a procedure could be used to influence performance in a positive rather than a negative manner.

In an adaptation of Herz's procedure (Epple and Herz 1999; Herz et al. 2004), our olfactory conditioning methodology comprises 3 phases; baseline, acquisition, and test. In the baseline phase, participants are presented with a set of tasks to complete without the presence of ambient odors and their performance is recorded. Following this, the acquisition phase presents participants with a task whose outcome, through a rigging of the task materials, has already

been biased toward a successful outcome and here, crucially, an ambient odor is present. In the test phase, participants are presented with a set of tasks similar in nature to those presented in the baseline phase. Again, there is an ambient odor present, and the specific quality of the odor is either the same as, or different to, that in the acquisition phase. Our index of the influence of ambient odor on task performance is the change in performance from baseline to test phases. The questions of interest are whether or not success in the acquisition phase has been represented in association with the ambient odor and whether the re-presentation of that odor influences subsequent task performance in the test phase. If so, we expect that the presence of the same odor at acquisition and test will result in a higher level of performance in the test phase than the presence of 2 different odors.

Should the results follow this pattern, a more parsimonious explanation could be that the mere presence of the same odor as at acquisition results in better performance, regardless of whether success was experienced in the acquisition phase. To demonstrate therefore that olfactory-related changes in performance are contingent upon the experience of success in the presence of that odor, we also include a neutral control group who experience the same odor at acquisition and test but do not experience success in the acquisition phase.

One important facet of Herz's successful studies (Epple and Herz 1999; Herz et al. 2004) is that the negative task outcome appears to engender an emotional response. Herz et al. (2004) asked participants to play a game, which initially brought them some success but was then followed by a frustrating decline into failure. Similarly, Epple and Herz (1999) asked children to solve a maze puzzle that appeared simple but had, unbeknown to them, been rendered impossible to complete. In each case, it seems that failing the task was accompanied by a negative emotional response, and it is clear that the experience of failure is not homogenous across all unsuccessful situations; failure is not merely the absence of success, and the emotional outcome of failing at a very difficult task is qualitatively different to failing at a very simple one. In the former, the emotional reaction (e.g., surprise, depression, self-doubt) would be much stronger than in the latter and, given that emotional and personally "significant" experiences are likely to be associated with richer and more complex processing, it is likely that affective experiences are more effective learning experiences. It is therefore important that, when considering the conditioning of positive behavior, the learning phase should involve a similarly affective response. With this in mind, our procedure involves an acquisition task that appears difficult at the outset but has been rigged to be easy to complete successfully. In doing this, we hope to inspire a stronger positive emotional reaction and a richer learning experience.

Further, it is unlikely that Herz's procedures (Epple and Herz 1999; Herz et al. 2004) resulted in a reduction in ability to complete the tasks. Rather, we concur with Herz that the procedure most likely affects motivation to achieve in the

presence of a particular odor, and it is the reduction in motivation that yields reductions in performance. Adhering to this rationale, it follows that a group of participants who already suffer problems with motivation will be most likely to benefit from an olfactory conditioning manipulation designed to boost motivation and subsequent performance. Therefore, our investigation involves individuals who were identified as underachieving and/or lacking in confidence, qualities that were most easily identified in schoolchildren. In the present study, therefore, we recruited underachieving schoolchildren and rigged an acquisition task to appear difficult but in fact be easy to complete successfully.

Herz et al. (2004) tentatively suggested a possible alternative explanation for their results that explained differences in performance according to evaluative conditioning (e.g., Baeyens et al. 1996; de Houwer et al. 2001) and acquired odor hedonics. According to this view, the negative experience in the acquisition phase in the presence of the ambient odor may have caused an acquired dislike of the odor such that, when the odor was later encountered, participants wanted to escape from the odor and may therefore have been distracted from the test task. On a less proximal level, interrelationships between ambient odor, emotion, and task performance are established in the literature. Pleasant odors can induce reported increases in positive affect (e.g., Knasko 1992, 1995) and related changes in physiological responses (e.g., Alaoui-Ismaili et al. 1997; Millot and Brand 2001) while there is converging evidence that positive affect exerts a consistently positive influence on a range of cognitive abilities (for review, see Ashby et al. 1999). It may therefore be that the source of this effect on behavior is simply through the presentation of a liked or disliked ambient odor, an explanation we term the affective mediation hypothesis. We therefore wished to investigate the possible influence of odor hedonics on task outcomes and gathered data on hedonic ratings of the odors used. If the affective mediation hypothesis is true, we expect that performance in the test task is related to ratings of the pleasantness of the ambient odor at test, whereas if our olfactory conditioning hypothesis is true, we expect that task performance at test should be contingent only on the presence of the same ambient odor as in the acquisition task, regardless of pleasantness.

Materials and methods

Participants and design

Seventy-six boys between the ages of 11 and 13 years were selected from 2 mainstream high schools in the northwest United Kingdom. Participants were selected according to 2 criteria; students belonged to the middle-ability teaching groups, and their school reports described them as “underachieving” or “lacking self-confidence.” Parents of the children were informed in writing concerning the nature of the study and were given the opportunity to remove their child

from the study if they wished. No participants reported any upper respiratory problems or problems with olfactory perception. This study utilized a 2-factor mixed design with group (same odor, different odor, and neutral control) as the between-group factor and time (baseline and test) as the within-group factor. Participants were assigned randomly to the same-odor ($n = 30$) and different-odor ($n = 28$) groups such that children of different ages were equally represented in each. The neutral control group was tested at a later date with similar age considerations ($n = 18$).

Materials

A “same-as” task and an “odd-one-out” task were used in the baseline and test phases of the study, whereas a “find-the-pair” task was used at acquisition. The same-as task required participants to look at a target picture and find an identical picture in a row of slightly dissimilar pictures. The task was presented on a single sheet with 6 rows of pictures, the left-most picture being the target picture and the remaining 5 pictures being the foils amongst which the correct target was hidden. The odd-one-out task required participants to pick out the picture in a row of 6 that was different to the rest of the pictures in the same row. Again the task was presented on a single sheet comprising 6 rows of 6 pictures. Two versions of the same-as and odd-one-out tasks were prepared and both tasks were scored in terms of number of seconds required for successful completion. The find-the-pair task was constructed such that it appeared difficult but was in fact easy to complete. The nature of the task was to find 2 identical pictures in a row of foils. The cover page of the task was clearly labeled as a task suitable for children older than the participant’s age (for participants in Year 8, the task was labeled “Year 9,” etc.). The task itself consisted of 10 rows of 9 pictures of objects where, in each row, 2 of the objects were identical. Importantly, however, the pictures had been digitally manipulated such that the 2 identical pictures in each row had been subtly enlarged on the page so that they were easy to pick out.

Herbal and fruit teas were used to infuse the testing environment with an ambient odor. Two teas were used; peppermint and strawberry (Twinings, London, UK). When required, fresh teas were made and placed in the test environment 10 min before the session began. All testing took place in a small room, and the odor from a single freshly brewed mug of tea was detectable in the small space available. Although this method of odorant presentation was undeniably unsophisticated, it served the purpose of delivering the odor into the room in a standard manner. As in all research involving ambient odors, there was a possibility of adaptation to odor and, because this possibility increases with longer odor exposure, test sessions were kept brief.

Procedure

The study comprised 3 phases, and participants were tested individually on 3 occasions during a single week, with each

phase being separated by approximately 48 h. In the baseline phase, participants were brought to the odorless test room and asked to complete the same-as task and the odd-one-out task as quickly as possible while the experimenter recorded completion times with a stopwatch. This phase lasted for no longer than 4 min. In the acquisition phase, participants in the same-odor and different-odor groups were brought to the test room where an odor (either peppermint or strawberry) had been released. Each odor was used equally often with each group. The experimenter explained that she had run out of age-suitable copies of the find-the-pair task and she would give the participant a version that was meant for an older child. It was explained that the participant would most likely find the task quite difficult but that he should “do his best anyway.” While this was explained, the coversheet of the task was visible on the table, clearly marked for a level higher than the participant. Again, the experimenter timed the completion of the task. Participants in the neutral control group were asked to complete a questionnaire concerning their hobbies and sporting interests and did not explicitly experience success in this phase. In all cases, the acquisition phase lasted for approximately 3 min. The test session was identical to the baseline session with the addition of the presence of either the same odor as in the acquisition phase (for the same-odor and neutral control groups) or the alternate odor (for the different-odor group) in the test room. When all tasks were complete, all participants were presented with both odors and asked to rate the pleasantness of each odor on a 7-point scale (1: very unpleasant, 7: very pleasant) before being debriefed.

Results

Mean baseline and test performance for participants in each condition and for each task are shown in Table 1 where task completion times in the same-odor group appear to improve more than those in the different-odor and the neutral control groups.

Performance times in the same-as task for the 3 conditions were entered into a 3 (group: same odor vs. different odor vs. neutral control) \times 2 (time: baseline vs. test) mixed analysis of variance. With the F values resulting from these analyses, we report the recently defined generalized eta squared (η_G^2 ;

Table 1 Mean same-as and odd-one-out task completion times (standard deviation) at baseline and test for each condition

Condition	Same-as task		Odd-one-out task	
	Baseline	Test	Baseline	Test
Same odor	26.33 (6.14)	19.03 (5.95)	33.70 (7.11)	24.50 (5.95)
Different odor	27.86 (8.13)	25.32 (7.85)	35.11 (6.60)	29.96 (7.04)
Neutral control	28.72 (7.93)	24.89 (5.98)	35.61 (5.33)	31.00 (5.72)

Both tasks are scored in terms of the number of seconds required to complete the task.

Olejnik and Algina 2003) as the effect-size statistic because it is comparable across studies with different designs and particularly appropriate in repeated-measures designs (Bakeman 2005). There was a main effect of group, $F(2,73) = 3.74$, $P = 0.03$, $\eta_G^2 = 0.07$, and Tukey's tests suggested that overall performance in the same-odor group was better than in the different-odor group. There was also a main effect of time, $F(1,73) = 34.45$, $P < 0.001$, $\eta_G^2 = 0.09$, indicating that performance at test was significantly faster than at acquisition. Importantly, there was a significant interaction between group and time, $F(2,73) = 3.99$, $P = 0.02$, $\eta_G^2 = 0.02$. Independent-samples t -tests comparing performance by the 3 groups at acquisition indicated that there were no differences in performance in this phase. However, similar analyses at test indicated that performance in the same-odor group was better than in the other 2 groups which themselves did not differ.

The same analysis was carried out on performance times in the odd-one-out task. Again, there was a main effect of group, $F(2,73) = 4.59$, $P = 0.01$, $\eta_G^2 = 0.08$, and Tukey's tests suggested that overall performance in the same-odor group was better than in the neutral control group. Similarly, there was a main effect of time, $F(1,73) = 55.23$, $P < 0.001$, $\eta_G^2 = 0.19$, indicating that performance at test was significantly faster than at acquisition. As with the same-as task, there was a significant interaction between group and time, $F(2,73) = 3.19$, $P = 0.047$, $\eta_G^2 = 0.03$, and t -tests again indicated that, in the test phase, performance in the same-odor group was better than in the other 2 groups which themselves did not differ.

To examine the possibility that odor hedonics may be responsible for this pattern of performance, we directly compared the test odor pleasantness ratings from the 3 groups of participants who experienced that odor at test. For groups who were tested in the presence of the peppermint odor, 1-way analysis of variance showed that there were no differences in rated pleasantness of the peppermint odor, $F(2,35) = 0.05$, $P = 0.95$, $\eta_G^2 = 0.03$. Similarly, analysis of rated pleasantness of the strawberry odor by groups experiencing that odor at test revealed no differences, $F(2,35) = 0.08$, $P = 0.92$, $\eta_G^2 = 0.004$. Mean hedonic ratings of test odor by different groups are shown in Table 2 where it can be seen that the groups, which have superior task performance at test (i.e., the same-odor groups), do not rate their test odor as being more pleasant than the groups who show weaker task performance.

Table 2 Mean ratings of pleasantness of test odor by participants who experienced the same or different odor in the acquisition phase

Test odor	Success acquisition odor		Neutral acquisition odor	
	Peppermint	Strawberry	Peppermint	Strawberry
Peppermint	4.13 (0.64)	4.21 (0.80)	4.22 (0.97)	—
Strawberry	4.93 (1.00)	4.80 (1.01)	—	4.78 (0.97)

Ratings are on a 7-point scale where 1 indicates “very unpleasant” and 7 indicates “very pleasant.”

Discussion

We have shown that ambient odors can be strategically applied to manipulate task performance in a positive manner. The performance of underachieving children on a paper-and-pencil task was significantly improved using a simple classical conditioning procedure where an odor became associated with a positive task-related experience. Herz's findings (Epple and Herz 1999; Herz et al. 2004) have suggested that creating a situation where failure accompanies an ambient odor establishes an association between the odor and a sense of demotivation such that the later presentation of the same odor weakens motivation to achieve. Our present investigation furthers our understanding of this effect by demonstrating that this can also be extended to improving achievement in underachieving schoolchildren. Significant improvements in performance were observed in comparison with control groups that experienced a different odor at test and to another control group that experienced the same odor at test but no success at acquisition. We have therefore shown that it is the contingency between odor and experience at acquisition that is the root of the effects shown here.

Thus far, we have been somewhat imprecise about the specific nature of the association that is created in the acquisition phase. That is, what exactly becomes associated with the ambient odor and what is the nature of the representations that are formed? Herz's (Epple and Herz 1999; Herz et al. 2004) work on the conditioning of weakened task performance proposes a clear emotional conditioning mechanism in line with the animal conditioning literature; the experience of failure inspires an emotional reaction that is represented in combination with the odor such that the later presentation of the same odor creates a similar emotional response that negatively influences performance. However, human reactions to their experience in our acquisition phase are likely to be multicomponential rather than solely emotional, and the acquisition experience is most likely comprised of a large number of constituent events. In succeeding at a task that appeared so difficult, the participant's experience is likely to include to some extent not only reactions of an emotional nature (e.g., joy and pride) but also reactions of a self-evaluative nature (e.g., confidence and greater self-esteem) and a behavioral nature (e.g., greater motivation and energy) as well as others. Given that there is no a priori reason to believe that one type of reaction lends itself more easily to the formation of associative representations than another, it is likely that the consequent association formed between odor and experience involves some measure of all of these reactions. Whether or not they are all necessary for the effect to occur however is a separate issue and cannot be answered by these data alone. We have not identified a more detailed theoretical model of the mechanism through which these effects emerge because it is uncertain at this point what the components of that model may be. It may be that an association solely between odor and emotional reaction may be

sufficient to produce these effects on performance and further investigations should focus on clarifying the necessary associative components for conditioned effects on performance to occur.

Herz et al. (2004) also tentatively suggest more complex alternative explanations involving some level of aversive and/or evaluative conditioning where, owing to its prior association with a negative experience, participants had come to dislike the odor and when it was presented later in the test phase, participants just wanted to escape from the disliked odor. Although the mechanism for this explanation is clear for Herz's data (Epple and Herz 1999; Herz et al. 2004), it is less clear how the same mechanism would function in the case of the conditioning of more positive behavioral responses. A second possibility, the affective mediation hypothesis, based on possible relationships between the presence of a pleasant odor, positive affect, and the consequent positive influence on cognitive abilities (e.g., Baron and Thomley 1994) is unlikely. Our data on ratings of the odors, which participants experienced with and without the experience of success, suggest no differences in preferences, and there is certainly no evidence to suggest that evaluative conditioning could be the source of the effect as regards positive performance. Nevertheless, the olfactory conditioning of positive and negative performances are not necessarily underpinned by the same mechanism, and Herz's proposals remain a possibility (albeit unlikely) as a process underpinning negative performance.

Despite the fact that these effects cannot be explained by simple affective mediation, we believe that emotion, and strength of emotion in particular, is a crucial aspect of olfactory conditioning, and effective associative links are more likely to be formed with stronger affective reactions. There is already other evidence that points to the formation of vivid episodic memories when events are particularly emotive or significant (e.g., Schulster 1989), and it may well be that affect strength is a mediating factor. However, in a situation such as in a laboratory task, where there is little personal investment or involvement in a task, strong emotional reactions are unlikely to emerge unless there is an unexpected outcome. That is, if participants were to be presented with what appeared to be a very simple task which they subsequently completed successfully, we would expect the degree of positive affect (or self-esteem or motivation) they experience to be substantially less than if, at the outset, the task appeared difficult and beyond the participant's normal capabilities. Thus, in our studies, an element of unexpectedness is likely to have contributed to the heightening of the subsequent response, and this is an important factor to be borne in mind in future studies. In addition, it may be no coincidence that unexpectedness at success may have had such an effect on children who were already identified as lacking in self-esteem, and it is likely that the response to success in such a sample of participants would be more marked than in a sample of children who were normally motivated and

confident in their abilities. Future work should therefore also examine the necessity of underachievement as a limiting condition and explore whether similar effects can be seen in normally achieving participants.

We have utilized a repeated-measures design in this study by administering one set of tasks in the baseline phase and measuring the change in performance on the same type of tasks at test. Although this allows a more precise measurement of the influence of odor on performance, it also has the effect of somewhat reducing the generalizability of these findings to other tasks. We believe that the speculative and exploratory nature of this investigation justifies such a methodological decision and have built controls into the design of the study that make its implications clear. Nevertheless, further research should incorporate a more varied range of tasks.

One omission in the present data concerns participants' conscious awareness of the ambient odors during the study and their ability to identify those odors. Previous work (Degel et al. 2001) has suggested that individuals may implicitly associate an odor and an environment only when they cannot identify that odor (also for an example of association without identification or awareness, see Kirk-Smith et al. 1983). Nevertheless, we did not collect data on odor awareness or identification, and it would be a limitation on these effects were it the case that only nonidentifiable odors were effective in this manner. Potentially this is an important issue. The odors used in the present study, peppermint and strawberry, are not uncommon, and it is likely that they would have been identified had our participants been asked to do so. However, unlike Degel et al. (2001), the nature of the association that is being represented in this situation is between an odor and an internal state rather than an external environment, and speculatively, this may be a crucial distinction. In any case, future work should seek to clarify this issue.

In summary, we present the first evidence that olfactory stimuli can be used in a classical conditioning paradigm to improve performance in human populations. When participants experience unexpected success in the presence of an ambient odor, the later presentation of that odor exerts a significantly positive effect on their performance as compared with those receiving a different odor and also those receiving the same odor but who did not experience success. The broadest implications of this work suggest that ambient odors can become associated with emotionally significant events and can be used to influence conscious behavior in a positive manner.

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