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Effects of Context on Judgements of Odor Intensities in Humans

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Abstract

This study evaluated whether the intensity of previously smelled odors could unintentionally influence the subsequent judgement of odor intensity. The predicted context effect was based on the adaptation-level theory. Before and 25 min after either WEAK or STRONG biasing odor concentrations, 51 subjects were required to rate the intensity of 10 different odor concentrations of California Orange Oil. After the WEAK bias, subjects judged the odor intensity as being stronger than they did after the STRONG bias. Thus the intensity of odors smelled 25 min earlier can unintentionally influence subsequent odor intensity judgement. The findings are discussed in the light of two alternative explanations, namely, a central implicit memory process and a stimulus-level-based change at the peripheral level.

Introduction

Context effects, or the dependence of judgement of stimuli upon the frame of reference, have been described for several kinds of stimuli, including weight, sound, light (Helson, 1947, 1948; Johnson, 1949; Benzing and Squire, 1989) and taste stimuli (Riskey *et al.*, 1979; Schifferstein and Frijters, 1992; Schifferstein, 1994). Such context effects can be explained by the adaptation level theory proposed by Helson (1947, 1948). This theory predicts that the combined effect of all prior stimuli influences subsequent judgements such that exposure to strong stimuli results in subsequent underestimation of a test stimulus, while exposure to weak stimuli results in subsequent overestimation of the stimulus. For olfactory stimuli, an increase in perceived odor intensity following exposure to another odorant has been described in adaptation experiments. The difference in the concentration of the adaptive stimuli and test stimuli resulted in overestimation of the perceived intensity of the test stimulus (Berglund *et al.*, 1978; de Wijk, 1989), but only during cross-adaptation (Köster and de Wijk, 1992). We developed a task in which subjects first had to judge 10 different intensities of a pleasant-smelling odor. Thereafter, in 20 biasing trials, subjects had to judge either the five lowest or the five highest intensities of the odorant. Finally, after a 25 min delay, the subjects re-evaluated the 10 original odor intensities. In line with Helson's theory, we hypothesized that exposure to the low-intensity odors (weak bias) would result in subsequent overestimation whereas exposure to the high-intensity odors (strong bias) would result in subsequent underestimation of odor intensity.

Materials and methods

Subjects

Thirty males and 30 females aged 18–30 years participated. Subjects were recruited by means of an advertisement placed in the university newspaper and were paid for their participation. Exclusion criteria were a cold within 3 weeks of the experiment, current neurological and/or psychiatric disorder, alcohol or drug abuse, and pregnancy or menstruation. After subjects had given their written informed consent, they were assessed individually in the morning by an experienced examiner. Intact odor detection (see description of odor detection task below) was used as criterion for inclusion.

Seven participants did not attain the odor detection level, one participant reached the detection level but evidenced a serious deficit in odor differentiation and one had a neurological disorder detected at the time of testing. Of the remaining 51 subjects 26 were included in the WEAK group and 25 in the STRONG group. There were no differences between the WEAK versus STRONG groups with respect to age (mean age ± SD was 22.7 ± 3.0 and 22.6 ± 2.9) and sex (12/14 and 13/12 males/females respectively).

Olfactory tasks

The odor detection task

The odor detection task was adapted from a task developed by Doty and co-workers (Doty *et al.*, 1986; Doty, 1991), and consisted of 16 trials in which a subject had to decide which of two 250 ml glass vials presented in fixed random order had the strongest smell. One bottle contained 18 ml of the odorant phenylethyl alcohol (PEA), a flower-like non-trigeminal odor (Doty *et al.*, 1978; Cometto-Muñiz and Cain, 1990), diluted in di-propylene glycol (DPG), an almost odorless substance, and the other bottle contained 18 ml DPG. On every other trial, the concentration of PEA in DPG was increased by 1 log step from –8.0 log vol/vol to –1.0 log vol/vol. The intertrial interval was kept at 20–30 s. A subject was considered to have intact odor detection ability when he or she first reached a score of four correct trials in a row (chance 6%). The highest concentration within these four trials was considered the detection level. If this criterion was not reached, the threshold could not be determined and the subject was not included in the study.

The odor intensity judgement tasks I and II

The odor intensity judgement biasing procedure consisted of three separate tasks, i.e. the odor intensity judgement tasks I and II, and the odor intensity comparison task (the bias). Odor intensity judgement tasks I and II both required the participants to judge the odor intensity of 10 different concentrations of suprathreshold cold-pressed, perfumery grade California Orange Oil (COO) diluted in DPG, ranging from –4.5 log vol/vol to 0 log vol/vol in 0.5 log steps, in a fixed random order, with the restriction that in two consecutive trials the concentration differed by at least 1 log step (2.0, 3.0, 0.0, 4.0, 1.0, 3.5, 0.5, 4.5, 1.5, 2.5 log vol/vol COO). The solutions were presented in 30 ml glass vials with white screw-on lids. The interstimulus interval was kept at 30 s. The glass vials were painted gray on the side and yellow on the bottom to prevent participants from getting visual cues concerning the different concentrations of the yellow odorant. Subjects indicated the strength of the solutions by placing a pencil mark on a 10 cm line drawn on a sheet of paper. The line represented a continuum ranging from 'very weak' to 'very strong'. The points were measured by the experimenter in centimeters from the 'very weak' end of the line.

The odor intensity comparison task

The odor intensity comparison task served as bias. The participants were not told of the relation between this task and the odor intensity judgement tasks. In the odor comparison task subjects compared the concentration of five different odor intensities as being weaker or stronger than the odor intensity in the preceding vial. Twenty 30 ml glass vials with gray screw-on lids, painted gray on the side and yellow on the bottom, were filled with five concentrations of COO. The subjects were blindly assigned to one or the other of two conditions. In the WEAK condition, the 20 glass vials contained the five weakest concentrations of COO used in the odor intensity judgement task, ranging from –4.5 log vol/vol to –2.5 log vol/vol in 0.5 log steps. The solutions were presented in a fixed random order; there was at least 1 log step difference in concentration between two consecutive stimuli (3.5, 4.5, 3.0, 4.0, 2.5, 4.5, 3.5, 2.5, 4.0, 3.0, 4.5, 3.5, 2.5, 4.0, 3.0, 4.5, 3.0, 4.0, 2.5, 3.5). In the STRONG condition, the 20 glass vials contained the five strongest concentrations of COO used in the odor intensity judgement task, ranging from –2.0 log vol/vol to 0 log vol/vol in 0.5 log steps. The solutions were presented in the same relative fixed random order as for the WEAK condition (1.0, 2.0, 0.5, . . . , 1.5, 0.0, 1.0). The interstimulus interval for both conditions was 30 s.

Procedure

Assessment took place in a room in which the humidity was kept constant at 70%, the temperature was 22°C and the air was cleaned continuously by a table-model charcoal filter. No odor bottle was opened more than once during the test session. The bottles were renewed every 2 weeks during the 6 month experimental period. Between test sessions the bottles were kept at 5°C.

Fifty minutes after completion of the odor detection task, the odor intensity judgement task I was performed. After an interval of 45–90 min, the odor intensity comparison task was completed. After a further delay of 25 min, the odor intensity judgement task II was completed. To prevent interference, in both intervals subjects completed other, non-odor-related, tasks.

Statistical analysis

For each subject, the sum of the ten scores (judgements) obtained during the pre-bias condition (pre-biasing score) and the sum of the ten perceived odor intensities in the post-bias condition were calculated (post-biasing score). The pre-biasing score was used to control for differences between groups prior to biasing. The individual *biasing score* was calculated by subtracting the pre-biasing sum score from the post-biasing sum score. The biasing effect was analyzed by MANOVA for the WEAK versus the STRONG groups (between factor) with respect to the pre-biasing score versus the post-biasing score (within factor). The odor detection level of the WEAK and STRONG groups was calculated by using Student's *t*-test for unrelated samples.

Results

Odor detection

The mean odor detection level was –3 log vol/vol PEA/DPG in both the WEAK and the STRONG groups ($t_{(49)} = 0.27$, n.s.).

Odor intensity judgement

In the pre-bias condition, odor intensity judgement did not differ between groups ($t_{(49)} = 0.31$, n.s.). A linear relation was observed between the log vol/vol increase in the odor intensity and the rating response (Figure 1a).

However, the two experimental groups (WEAK and STRONG) did differ in the effects of biasing [$F(1,49) = 7.66$,

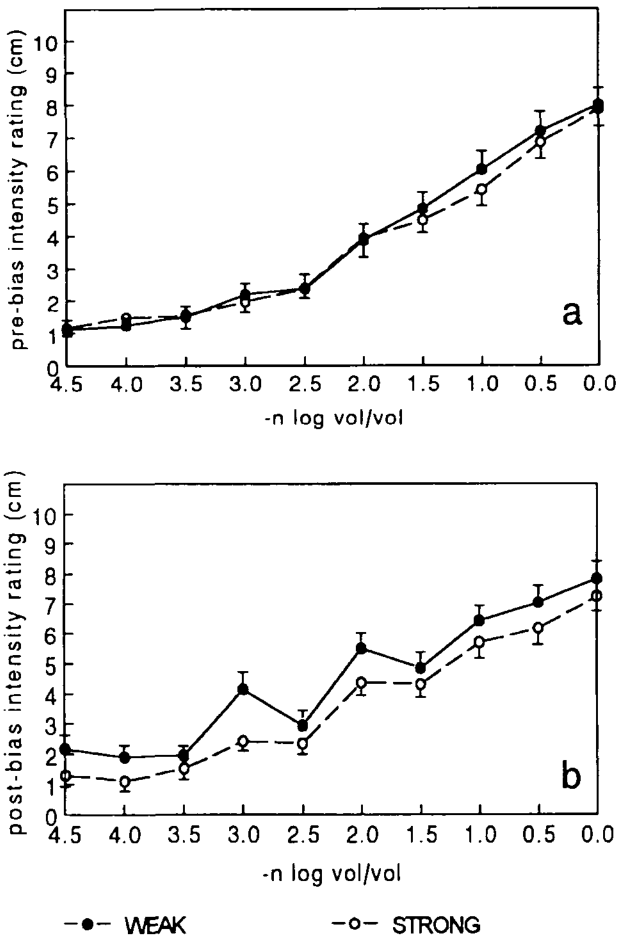

Figure 1 Mean (± SE) perceived odor intensity (ranging from 0, weak to 10, very strong) in the pre-bias condition **(a)** and in the post-bias condition **(b)** for the WEAK and STRONG condition groups. Ten different concentrations of California Orange Oil (COO) diluted in di-propylene glycol, ranging from –4.5 to 0.0 log vol/vol separated by half-log steps (plotted in increasing concentrations of COO; see text for order of presentation), were used.

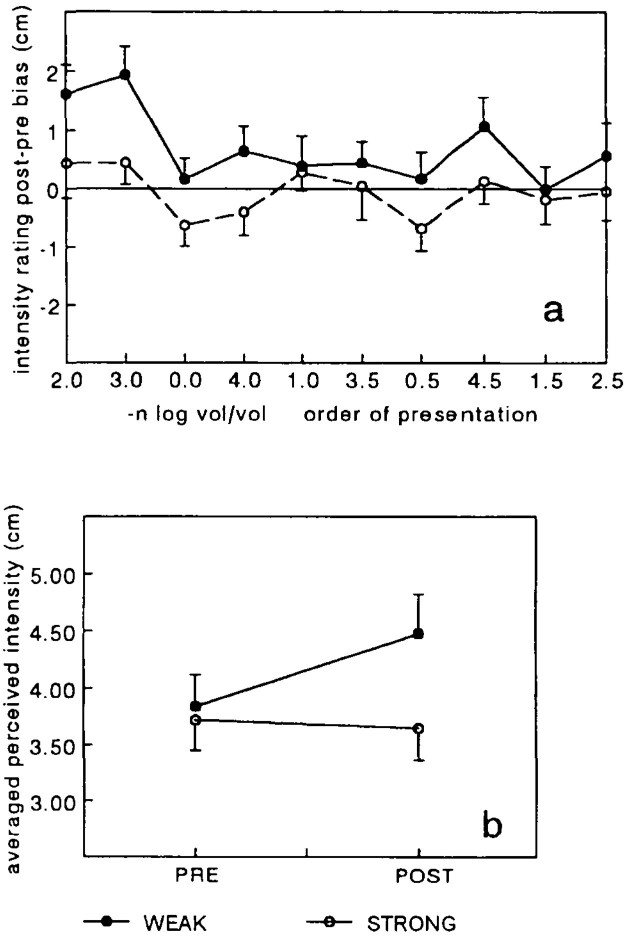

Figure 2 Mean (± SE) biasing score of the perceived odor intensity in the post-bias minus pre-bias condition of the WEAK and STRONG condition groups in order of presentation **(a)** and of average **(b)**. Assessment, ranging from very weak (0) to very strong (10), of ten different concentrations of California Orange Oil diluted in di-propylene glycol, ranging from –4.5 to 0.0 log vol/vol separated by half-log steps.

$P < 0.01$) (Figures 1b and 2). The effect was found throughout the 10 trials but was strongest in the first two trials (with –2.0 and –3.0 log vol/vol PEA in DPG) (Figure 2a). The mean ± SE biasing score was 6.4 ± 1.1 cm in the WEAK group and –0.1 ± 1.1 cm in the STRONG group (Figure 2b). Thus, after the WEAK bias the odor intensities were considered as stronger than after the STRONG bias.

Discussion

Exposure to weak or strong odor intensities influenced judgements of odor intensities smelled 25 min later. This was evidenced by the effect of the WEAK versus STRONG odor intensity bias in subjects who had not been told that there was any relation between the bias and the odor intensity judgement. Subjects who smelled the WEAK odors overestimated odor intensity compared with their evaluation of the same odor intensity before biasing. No such effect occurred in subjects exposed to the STRONG odors. Although we did not control for unbiased changes in intensity judgement during the 25 min inter-test interval, it is unlikely that a general sensitization contributed to the results, because judgement of odor intensity (without bias) does not change over time (Algom and Cain, 1991).

We had hypothesized that bias would act according to the adaptation-level effect: biasing with weak intensities would result in overestimation of subsequent odor intensities and biasing with strong intensities would instead result in subsequent underestimation. The predicted effect was only partly confirmed by the data. While the weak bias indeed resulted in subsequent overestimation of odor intensity, the strong bias did not affect odor intensity estimation.

Whether odor intensity bias occurs via peripheral or central processes cannot be answered with certainty.

Manipulation of the time intervals between the bias and post-bias conditions could result in more definitive conclusions. However, given that there was a 25 min delay between the bias and the odor intensity test, biasing probably reflects a central, cognitive process rather than a peripheral, perceptual effect (Moore, 1994). Although recovery from adaptation is dependent on the duration and intensity of the preceding adapting stimulus, recovery from olfactory adaptation is thought to take 15–20 min (Köster, 1971). Thus, even when a peripheral effect is found after 25 min, it cannot be explained at the level of the receptor only but must also involve a central process (Potter and Chorover, 1976). Further, Stevens (1975) suggested that the adaptation level effect does not reflect an adaptation of a sense organ.

Although in our study the context effect was manipulated in such a way that it could operate independently of explicit verbal or visual processing, implicit verbal or visual involvement in the bias could not be excluded. Indeed, it has been suggested that the adaptation level effect is based on the subject's scale of judgement, which is adjusted according to the assortment of stimuli the subject is asked to categorize, also called semantic adjustment (Stevens, 1958). In this respect, the biasing effect found in the present study could have resulted from changes in implicit verbal labeling of the olfactory intensities.

The mechanism responsible for the observed changes in responses to olfactory stimuli observed is not known. Possibly, the context effect for odor intensities may represent an implicit memory process. Implicit memory is demonstrated by the facilitatory effect of previous exposure to a stimulus on subsequent processing of the same stimulus (or a related one) in the absence of any conscious recollection of the previous experience (e.g. Graf and Schacter, 1985). Implicit memory for odors has been shown, but not consistently, by using a combination of the odor quality and its identification (Wippich *et al.*, 1989; Schab and Crowder, 1995). In our experiment the context effect lasted 25 min and was introduced without the subjects being informed, thus requiring the implicit storage of odor intensity information perceived earlier.

Alternatively, some kind of stimulus-range- or stimulus-level-based change in the 'gain' of the perceptual system may have occurred. The existence of a nonlinear amplifier has been suggested whose gain and degree of nonlinearity are adjusted under top-down control, so as to prevent distortion and to increase discriminability. In two experiments measuring effects of context on judgements of loudness, sounds of low sound-pressure levels induced an increase in 'gain' or augmentation of loudness (and in the log–log slope of the loudness function) whereas sounds of high sound-pressure levels had no effect (Schneider and Parker, 1990; Parker and Schneider, 1994). The nonlinear amplifier is considered to reside in the periphery of the auditory system and is modified by a central process that keeps track of the loudness of recently heard noises (Parker and Schneider, 1994). If such a system exists for odor intensity, it could explain the findings in our study that the weak bias resulted in subsequent overestimation of odor intensity whereas the strong bias did not affect odor intensity estimation.

In summary, the present findings show that odor intensities smelled 25 min earlier can unintentionally influence subsequent odor intensity judgement in humans. In particular, low odor intensity biasing resulted in an overestimation of subsequent odor intensities.

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References

Algom, D. and **Cain, W.S.** (1990) *Remembered odors and mental mixtures: tapping reservoirs of olfactory knowledge*. J. Exp. Psychol.: Hum. Percept. Perform., 17, 1104–1119.

Benzing, W.C. and **Squire, L.R.** (1989) *Preserved learning and memory in amnesia: intact adaptation-level effects and learning of stereoscopic depth*. Behav. Neurosci., 103, 538–547.

Berglund, B., Berglund, U. and **Lindvall, T.** (1978) *Separate and joint scaling of odor intensity of n-butanol and hydrogen sulfide*. Percept. Psychophys., 23, 313–320.

Cometto-Muñiz, J.E. and **Cain, W.S.** (1990) *Thresholds for odor and nasal pungency*. Physiol. Behav., 48, 719–725.

de Wijk, R.A. (1989) Temporal Factors in Human Olfactory Perception. Doctoral thesis, University Utrecht.

Doty, R.L., Brugger, W.E., Jurs, P.C., Orndorff, M.A., Snyder, P.J. and **Dale Lowry, L.** (1978) *Intranasal trigeminal stimulation from odorous volatiles: psychometric responses from anosmic and normal humans*. Physiol. Behav., 20, 175–185.

Doty, R.L., Gregor, T.P. and **Settle, G.** (1986) *Influence of intertrial interval and sniff-bottle volume on phenyl ethyl alcohol odor detection thresholds*. Chem. Senses, 11, 265–282.

Doty, R.L. (1991) *Psychophysical measurement of odor perception in humans*. In Laing, D.G. Doty, R.L. and Breipohl, W. (eds), The Human Sense of Smell. Springer-Verlag, Berlin, pp. 97–134.

Graf, P. and **Schacter, D.L.** (1985) *Implicit and explicit memory for new associations in normal and amnesic subjects*. J. Exp. Psychol.: Learn. Mem. Cogn., 11, 501–518.

Helson, H. (1947) *Adaptation-level as frame of reference for prediction of psychophysical data*. Am. J. Psychol., 60, 1–29.

Helson, H. (1948) *Adaptation-level as a basis for a quantitative theory of frames of reference*. Psychol. Rev., 55, 297–313.

Johnson, D.M. (1949) *Learning function for a change in the scale of judgment*. J. Exp. Psychol., 30, 851–860.

Köster, E.P. (1971) Adaptation and Cross-adaptation in Olfaction. Doctoral thesis Utrecht University, Bronder-Offset N.V., Rotterdam.

Köster, E.P. and **de Wijk, R.A.** (1992) *Olfactory adaptation*. In Laing, D.G. Doty, R.L. and Breipohl, W. (eds), The Human Sense of Smell. Springer-Verlag, Berlin, pp. 199–215.

Moore, P.A. (1994) *A model of the role of adaptation and dysadaptation in olfactory receptor neurons: implications for the coding of temporal and intensity patterns in odor signals*. Chem. Senses, 19, 71–86.

Parker, S. and **Schneider, B.** (1994) *The stimulus range effect: evidence for top-down control of sensory intensity in audition*. Percept. Psychophys., 56, 1–11.

Potter, H. and **Chorover, S.L.** (1976) *Response plasticity in hamster olfactory bulb: peripheral and central processes*. Brain Res., 116, 417–429.

Riskey, D.R., **Parducci, A.** and **Beauchamp, G.K.** (1979) *Effects of context in judgments of sweetness and pleasantness*. Percept. Psychophys. 26, 171–176.

Schab, F.R. and **Crowder, R.G.** (1995) *Implicit measures of odor memory*. In Schab, F.R. and Crowder, R.G. (eds), Memory for Odors. Mahwah, NJ, Lawrence Erlbaum Assoc., pp. 71–91.

Schifferstein, H.N.J. (1994) *Contextual effects in the perception of quinine HCl/NaCl mixtures*. Chem. Senses, 19, 113–123.

Schifferstein, H.N.J. and **Frijters, J.E.R.** (1992) *Contextual and sequential effects on judgments of sweetness intensity*. Percept. Psychophys., 52, 243–255.

Schneider, B. and **Parker, S.** (1990). *Does stimuli context affect loudness or only loudness judgments?* Percept. Psychophys., 48, 409–418.

Stevens, S.S. (1958) *Adaptation-level vs. the relativity of judgment*. Am. J. Psychol., 71, 633–646.

Stevens, S.S. (1975) Psychophysics. John Wiley & Sons, New York.

Wippich, W., **Mecklenbrauker, S.** and **Trouet, J.** (1989) *Implizite und explizite Erinnerungen an Geruche*. Arch. Psychol., 141, 195–211.

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