Food Quality and Preference 50 (2016) 145–151

Contents lists available at ScienceDirect

Food Quality and Preference

journal homepage: www.elsevier.com/locate/foodqual

Eating in the dark: A dissociation between perceived and actual food consumption

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ARTICLE INFO

Article history:
Received 9 September 2015
Received in revised form 5 February 2016
Accepted 9 February 2016
Available online 10 February 2016

Keywords:
Blind
Sight
Food intake
Food perception
Eating
Food taste
Visual cues
Vision

ABSTRACT

Objective: According to folk intuition "Eye appeal is half the meal," raising the question how the absence of vision or 'visual flavor' affects food perception, willingness to buy, and food intake. *Method:* In the present experiment, ninety students were assigned to either a blindfolded or a non-blindfolded condition and completed a bogus ice cream taste test. Taste perceptions and purchase willingness were assessed during tasting, and actual and perceived intake, afterward. *Results:* Blindfolded participants rated the ice cream lower on hedonic but higher on ambiguity taste attributes. Although eating without vision led to a lower purchase willingness and a 9% decrease in the actual intake, blindfolded participants overestimated their intake by 88% while non-blindfolded overestimated their intake only by 35%. *Conclusions:* Thus, depriving participants of visual input dissociated perceived intake from actual intake. Shifting attention toward interoceptive cues of eating may provide unobtrusive and naturalistic means to change eating experiences.

1. Introduction

Human eating behavior is a fascinating and complex system. Most of the behavioral eating repertoire is not innate, and the system is highly adaptive to the environment. This becomes obvious when we consider that human beings can adapt to eat virtually anything. For example, mud or soil, which most human beings would not consider as eatable, has recently become a special ingredient at some of Japan's high-end restaurants. News outlets such as CNN and The Japan Times featured chef Toshio Tanabe, the inventor of the new *tsuchi ryōri* ("earth cuisine") which includes courses from appetizers to desserts that are based on real earth from the ground (Swinnerton, 2013; Zolbert, 2013).

From this point of view, eating behavior can be conceptualized as an embodied behavior system (Ghane & Sweeny, 2013). This means that our behavioral eating responses, our thoughts, feelings, and observable behavior related to food intake, are the result of bodily interactions with the food environment. We react to food based on our five senses, and vision is particularly important for food choice and eating (see also Wadhera & Capaldi-Phillips, 2014). Folk wisdom tells us that "eye appeal is half the meal", and scientific evidence confirms this idea. Visual cues determine the hedonic appeal of food by triggering hedonic anticipations or, as Spence and Piqueras-Fiszman (2012) have phrased it, they trigger the 'visual flavor'. Thus, the visual system is key for physiological, emotional, and cognitive responses toward food (Schupp & Renner, 2011; van der Laan, de Ridder, Viergever, & Smeets, 2011). In contrast, public health interventions often recommend eating regulation strategies that rely on the cognitive system in order to navigate the complex food environment. For example, dietary guidelines or nutrition facts are rather abstract and cognitive; most people probably cannot see, smell, or taste a food when presented with nutrition facts. Thus, knowing the nutrition facts does not tell us which food it is and what it looks like, and whether it is green or red, fluffy or mushy, aromatic or bland. Considering this, the question arises whether food perception and eating behavior change when consumers are sensorily deprived; that is, what happens to our behavioral eating responses when we cannot see the food we are eating?

Only a few studies have examined the impact of vision on eating behavior so far (see for an overview Spence & Piqueras-Fiszman, 2012; Wadhera & Capaldi-Phillips, 2014). In a first, pioneering experimental study, Linné, Barkeling, Rössner, and Rooth (2002) asked normal-weight participants to eat a set test-meal lunch once with and once without a blindfold. When blindfolded, participants ate 22% less food but felt just as satiated as

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http://dx.doi.org/10.1016/j.foodqual.2016.02.010
0950-3293/

when eating without a blindfold. A similar pattern was observed within obese subjects eating a set lunch (Barkeling, Linné, Melin, & Rooth, 2003) or breakfast (Burger, Fisher, & Johnson, 2011) with an observed decrease in intake between 12% and 24% in the blindfolded compared to the non-blindfolded condition. Conversely, Scheibehenne, Todd, and Wansink (2010) studied food intake during a set lunch in a "dark" restaurant and found that (in the so-called "regular portion size" condition) food intake was 6% higher than when the restaurant was normally lit. However, people tended to empty their plate: in the dark, participants ate 96% of the amount served. This suggests that portion size was the leading cue for consumption in the dark condition, resulting in a higher consumption overall compared to the normally lit condition (see also Wansink, Shimizu, Cardello, & Wright, 2012).

In all previous studies, people received a complete meal. Since people have a tendency to view the portion they are being served as appropriate and normal, portion size norms (Burger et al., 2011; Herman & Polivy, 2008; Scheibehenne et al., 2010) may have affected the observed results. Likewise, the served complete meals were intended as a free substitute for a regular meal; thus, financial concerns may have influenced the results. In order to decrease the potential influence of portion size norms and financial concerns inherent in serving a complete substitute meal, the present study used a taste test paradigm with several portions of one food item (ice cream). Furthermore, Wansink and colleagues (2012) suggested that vision deprivation might increase the perceived ambiguity of the food, leading to a decrease in willingness to consume the food in the future. However, this contention has not explicitly been investigated, yet.

Extending these meal-based studies examining the impact of visual deprivation, the present study assessed, in addition to actual food intake, also other outcome variables in order to shed more light on the mechanisms. During the food intake session, taste and texture perception as well as approach behavior such as willingness to buy the product indicating acceptance of the food sample were measured. We assessed taste perception 'online' – that is, in real time during the food intake process – and not post-meal (see for example Burger et al., 2011; Scheibehenne et al., 2010), in order to reduce potential memory effects due to retrieving prior experiences (see Robinson, 2014). Moreover, perceived food intake was assessed indicating the ability to monitor food intake. Taken together, we examined the effect of visual deprivation on four different response modes: (1) taste perceptions, for example, how much participants like what they eat and whether they perceive the food as ambiguous; (2) willingness to buy the product; (3) intake behavior, i.e. how much participants actually eat; and (4) the ability to monitor food intake, i.e. how much participants think they eat.

2. Material and methods

2.1. Sample

Ninety participants from the University of Konstanz took part in the experiment. No participant was excluded; however, the numbers of observations vary slightly due to missing values. List-wise deletion per analysis was applied to handle missing data. Thus, if any single value was missing, the case was excluded from analysis. However, rate of missing data was low with a maximum of two missing per variable. Participants were assigned to one of two experimental conditions: blindfolded ($n = 50$) and non-blindfolded ($n = 40$). For practical reasons, the conditions were not run simultaneously but one after the other on a rolling basis. The non-blindfolded condition was run first. Participants had a mean age of 22.5 years ($SD = 4.1$) and a mean body mass index (BMI) of 21.8 kg/m^2 ($SD = 3.0$). Sixty-two of the participants were female (69%) and 28 were male (31%). For more details on participant characteristics see also Table S1 in the Supplementary Material available online. Participants received €8 for participation or course credit.

2.2. Procedure and materials

Participants arrived at the laboratory with the understanding that they would be taking part in a study about tasting. To decrease possible differences in initial hunger level, we informed participants when they scheduled an appointment that they should refrain from eating for two hours before participation.

The outside temperature was recorded as a control variable. After giving informed consent, participants filled in a brief questionnaire assessing their demographics, baseline hunger (rated on a 6-point scale ranging from 1 = very hungry to 6 = very satiated), and general liking of the ice cream ("I like ice cream" rated on a 4-point scale ranging from 1 = completely disagree to 4 = completely agree). Several additional variables were assessed at baseline.[1] These variables are not the focus of the current paper and are reported only in the interest of full disclosure. Afterward, actual food intake was assessed by a bogus taste test (e.g., Sproesser, Schupp, & Renner, 2014). Bogus taste tests assess actual consumption of foods, thereby omitting the bias of self-reports or retrospective memories of eating behavior (e.g., Evers, de Ridder, & Adriaanse, 2009).

Participants were provided with three individual-sized cups of Grandessa® ice cream which is sold by retailers in Germany. Three different popular flavors were presented to the participants: Amarena Cherry, Caramel, and Spaghetti (a typically German type of ice cream which consists of vanilla ice cream pressed through a shape to resemble the shape of cooked spaghetti and strawberry sauce to simulate tomato sauce). Each cup weighed approximately 95 g, equivalent to 188 kcal. A standard tea spoon accompanied each of the three cups. Participants were asked to evaluate the taste and texture of the ice cream as well as how much they liked it by rating basic taste aspects including hedonic appeal, ambiguity, naturalness, freshness, as well as texture and mouth feeling. Specifically, the taste test included 17 questions per ice cream flavor aiming at a comprehensive evaluation of the ice creams (e.g., "How much do you like this ice cream?" or "How surprising is the taste of this ice cream?") with a 4-point response scale ranging from 1 (not at all) to 4 (very much; cf. Sproesser et al., 2014, see also Evers et al., 2009 and Table S2 in the Supplementary Material available online). As there were no a priori reasons to assume differences in taste ratings between the three ice creams, and as the impact of the condition did not differ across the three flavors, taste ratings were summarized across the three flavors for analyses. In addition, willingness to purchase was measured separately for each presented ice cream on a 4-point scale from 1 (very unlikely) to 4 (very likely) and summarized across the three flavors for analyses.

The three ice cream bowls were placed in a handcrafted wooden mount. Participants were told to taste and eat as much as they liked. For effective blindfolding, participants wore modified ski goggles and a plastic cape to protect their clothing in case of spillage. Since blind-folded participants could not fill in the taste rating questionnaire, an audio questionnaire, programmed in Presentation®, was implemented in this condition. Participants could navigate the questions using foot pedals (start question, stop) and answered the questions aloud. A microphone in the room

[1] The other variables that were assessed at baseline were positive and negative affect, trait motives for eating, external and internal influences on eating, and tendency to eat when stressed.

transmitted their responses to an adjacent room, where the experimenter recorded them in real time. The sessions were videotaped (with participants' consent). During the taste test, the experimenter left the room.

After 15 min, the experimenter returned and administered another brief questionnaire that assessed perceived intake. To assess perceived intake, participants were asked to rate their intake in an open question format ("How many grams of ice cream X did you eat?"), and an anchor was presented stating that one spoon typically contains 9 g of ice cream. Perceived consumption for the three ice creams was added to establish a measure of total perceived intake. In addition, trait variables such as restrained eating (routine and compensatory restraint, Schembre, Green, & Melanson,, 2009, rated on an 5-point scale ranging from 1 = does not describe me at all to 5 = describes me completely) and subjective health (rated on an 5-point scale ranging from 1 = poor to 5 = excellent) were assessed (for more details, see Table S1 in the Supplemental Material available online). Finally, each participant's height and weight were measured. Moreover, the experimenter collected the bowls with food and weighed them in a separate room. Actual consumption was computed by subtracting the post-taste weight from the pre-taste weight for each of the three ice cream bowls. The three amounts were then added to establish a measure of total consumption.

The ethics committee of the University of Konstanz approved the study protocol. The study was carried out in accordance with the provisions of the World Medical Association Declaration of Helsinki.

3. Results

3.1. Descriptive analyses

T-Tests showed that participants in the non-blindfolded and blindfolded condition did not differ in age (22 vs. 23 years), BMI (21.9 vs. 21.7 kg/m^2), general liking of ice cream (3.7 vs. 3.6), restrained eating (1.9 vs. 1.8 for routine restraint and 2.6 vs. 2.6 for compensatory restraint), or subjective health (4.0 vs. 4.0; $|t|$'s $\leqslant$ 1.21, p's $\geqslant$ .228; details provided in Table S1 in the Supplementary Material available online). A significant difference between the two groups was found for outside temperature, $t(88) = 2.61$, $p = .011$, with a higher average outdoor temperature for the non-blindfolded group ($M = 13.90$ °C, $SD = 5.57$) as compared to the blindfolded group ($M = 9.82$ °C, $SD = 8.55$). In addition, the non-blindfolded group ($M = 2.75$, $SD = 0.98$) reported on average (nearly significantly) more pre-consumption hunger as compared to the blindfolded group ($M = 3.20$, $SD = 1.14$, $t(88) = -1.98$, $p = .051$. Further analyses were therefore conducted to statistically control for the influence of outside temperature and hunger.

3.2. Taste perceptions

In order to examine whether vision deprivation affects taste perceptions, mean ratings between the two experimental conditions were compared. As Fig. 1 shows, both groups rated the ice cream positively, and across the two groups, ratings differed between the 17 taste ratings. For example, the ice cream was rated higher on palatability than naturalness. Importantly, while the blindfolded and non-blindfolded groups showed a similar overall profile of the mean taste ratings, they nevertheless differed on mean levels for specific taste ratings. A MANOVA including the 17 taste ratings and condition (non-blindfolded vs. blindfolded) as between-subjects factor confirmed that there was a significant multivariate effect: Hotelling's $T = 1.40$, $F(17, 64) = 5.27$, $p < .001$, $\eta_p^2 = .583$. Specifically, hedonic taste ratings such palatability were

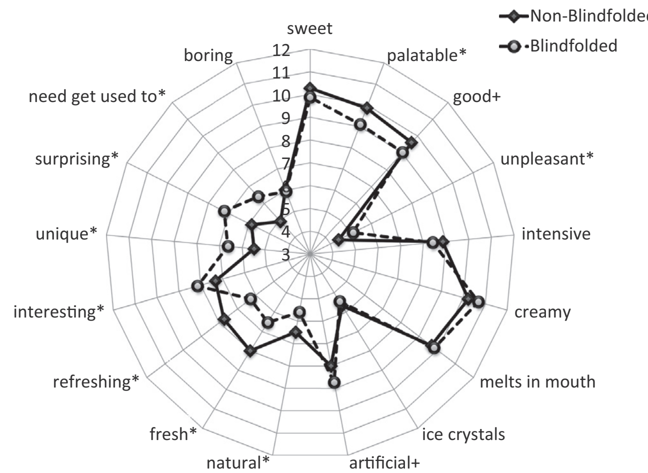

Fig. 1. Taste ratings (sum scores across three types of ice cream, potential range between 3 and 12). + $p \leqslant .10$, * $p < .05$.

rated higher, $t(87) = 2.03$, $p = .046$, or, in the case of unpleasantness (negatively scored) lower, by the non-blindfolded group compared to the blindfolded group, $t(88) = -2.25$, $p = .027$. Moreover, the non-blindfolded group believed that the ice cream tasted more natural, $t(87) = 2.36$, $p = .021$ and they gave lower, albeit not significantly, ratings for artificiality, $t(88) = -1.80$, $p = .076$. Likewise, the two freshness-related ratings were higher in the non-blindfolded group than in the blindfolded group, t's (88) $\geqslant$ 3.23, p's $\leqslant$ .002. Conversely, for ratings related to the ambiguity of the taste experience, such as surprise and the need to get used to the taste, the blindfolded group gave higher mean ratings than the non-blindfolded group, t's (88) $\geqslant -3.59$, p's $\leqslant$ .001. In a similar vein, uniqueness of the taste was rated higher by the blindfolded group, $t(88) = -2.95$, $p = .004$, and they also found the taste more interesting, $t(87) = -2.28$, $p = .025$. For texture-related taste ratings such as creaminess, melting, and ice crystals, no significant group differences were found, t's $\leqslant$ 1.45, p's $\geqslant$ .152. The other ratings also did not differ significantly between the two groups, t's $\leqslant$ 1.66, p's $\geqslant$ .101. Exact means, standard deviations, p-values, and Cohen's d are provided in Table S2 in the Supplementary Material available online.

3.3. Willingness to buy

In a subsequent t-test, the question of how vision deprivation affects the willingness to buy the food product was examined. The results show that the blindfolded group ($M = 2.2$, $SD = 0.62$) was less willing to buy the served ice cream in the future as compared to the non-blindfolded group, ($M = 2.5$, $SD = 0.51$), $t(88) = 2.15$, $p = .034$.

3.4. Actual and perceived intake

In subsequent analyses, it was examined how vision deprivation affects the actual amount of intake and the monitoring of the intake (i.e., perceived consumption) that is whether the discrepancy between actual and perceived intake differs across participants in the non-blindfolded and blindfolded condition. We conducted a two-way repeated measures ANOVA with type of intake (actual intake in grams vs. perceived intake in grams) as repeated measurement factor and condition (non-blindfolded vs. blindfolded) as between-subjects factor. The main effect for condition was not significant, which indicates that visual deprivation (non-blindfolded: $M = 137$ g, $SE = 16.3$ g; blindfolded:

M = 151 g, SE = 13.4 g, $F(1, 82) = 0.48$ $p = .491$, $\eta_p^2 = .006$), did not affect food intake across perceived and actual intake. However, a significant main effect for the type of intake emerged, $F(1, 82) = 32.16$, $p < .001$, $\eta_p^2 = .28$, indicating that the actual intake (M = 110 g, SE = 7.7 g) was significantly lower than the perceived intake (M = 178 g, SE = 15.3 g). This main effect was further qualified by a significant condition x type of intake interaction, $F(1, 82) = 4.47$, $p = .038$, $\eta_p^2 = .05$.

The condition x type of intake interaction is further broken down in Fig. 2. As Fig. 2 depicts, the non-blindfolded group actually consumed 116 g (SE = 11.8 g) and the blindfolded group actually consumed 105 g (SE = 9.7 g). Thus, the blindfolded group ate 9% less ice cream than the non-blindfolded group, although this difference was not significant. Interestingly, for perceived consumption, an inverted pattern of results emerged. The non-blindfolded group believed that they had eaten on average 158 g (SE = 23.6 g), and the blindfolded group thought that they consumed on average 197 g (SE = 19.5 g). Most importantly, together, these results show that the discrepancy between perceived and actual consumption was much larger in the blindfolded group than in the non-blindfolded group. Comparing the perceived and actual intake within the two experimental conditions shows that participants in the non-blindfolded group significantly overestimated their intake by 35%, $F(1, 82) = 5.32$, $p = .024$, $\eta_p^2 = .06$. However, this overestimation effect was much more pronounced in the blindfolded group, where participants overestimated their intake by 88%, $F(1, 82) = 37.42$, $p < .001$, $\eta_p^2 = .31$.

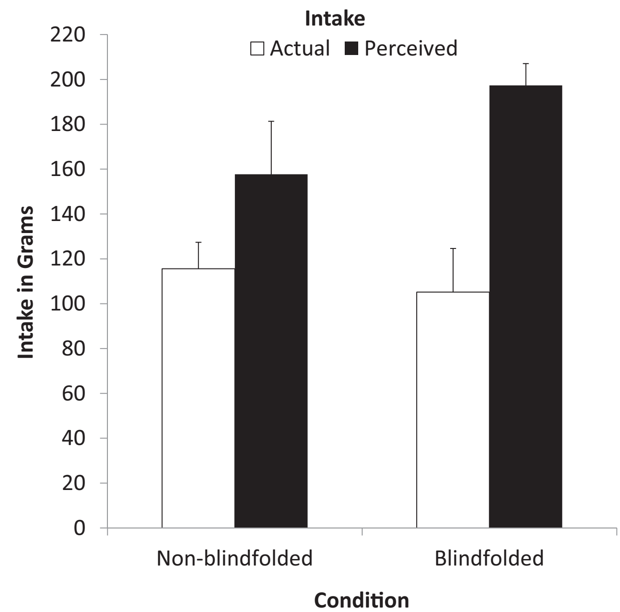

Fig. 2. Consumed ice cream in grams in dependence of condition and type of intake. Error bars indicate standard errors of the mean.

3.5. Control analyses

Since the two groups differed regarding reported pre-consumption hunger and measured outdoor temperature, additional control analyses were undertaken to ensure that the obtained pattern of results could not be attributed to differences in these variables. For this purpose, two ANCOVAs, with willingness to buy as dependent variable and condition (non-blindfolded vs. blindfolded) as between-subjects factor, were conducted with hunger and outside temperature as covariate, respectively. Both ANCOVAs yielded no significant effect for hunger or outdoor temperature, F's$(1, 87) < 0.108$, p's $\geqslant .743$. Moreover, the effect of condition with lower willingness to buy within the blindfolded condition, was still significant after controlling for hunger, $F(1, 87) = 4.19$, $p = .04$, or temperature, $F(1, 87) = 3.91$, $p = .05$.

In addition, two-way repeated measure ANCOVAs were conducted with type of intake (actual intake in grams vs. perceived intake in grams) as repeated measurement factor, condition (non-blindfolded vs. blindfolded) as between-subjects factor, and hunger as well as outside temperature as covariate, respectively. Neither outdoor temperature nor hunger was significantly related to type of intake, F's$(1, 81) \leqslant 0.196$, p's $\geqslant .659$ for main effects and F's$(1, 81) \leqslant .197$, p's $\geqslant .658$ for interaction effects. However, probably due to reduced power, the interaction terms between type of intake (actual vs. perceived) and condition (blindfolded vs. non-blindfolded) did not reach the <.05 significance threshold in the analyses including covariates, though the effect sizes remained virtually unchanged. Again, a greater overestimation was observed within the blindfolded group (actual intake: 108.9 g vs. perceived intake: 203.8 g) than in the non-blindfolded group (actual intake: 114.2 g vs. perceived intake: 158.9 g) when controlling for outside temperature, $F(1, 81) = 3.92$, $p = .051$, $\eta_p^2 = .05$). Also, a greater overestimation was observed within the blindfolded group (actual intake: 106.3 g vs. perceived intake: 197.7 g) than in the non-blindfolded group (actual intake: 113.4 g vs. perceived intake: 157.2 g) when controlling for hunger, $F(1, 81) = 3.90$, $p = .052$, $\eta_p^2 = .05$).

4. Discussion

The present experiment examined the effects of visual deprivation on food perception and eating responses. The results showed that participants were significantly less willing to buy the food product and ate 9% less when blindfolded than when seeing (although the latter results was not statistically significant). The amount of intake reduction is slightly lower than in previous studies on normal-weight participants who were served a set lunch (Barkeling et al., 2003; Linné et al., 2002) or breakfast (Burger et al., 2011). This difference might be due to the type of eating situation (taste test vs. full substitute meal). Moreover, the observed difference in willingness to buy and actual intake for the blindfolded and non-blindfolded groups might have been caused by differences in internal states of satiety. Both groups were asked to refrain from eating for two hours before participation, nonetheless the blindfolded group reported lower pre-testing hunger. However, including hunger as covariate in the analyses did not yield a significant effect on the dependent variables, suggesting that the internal need of hunger might not have been the only force driving the observed approach behavior (see also Wansink & Chandon, 2014).

Interestingly, the observed pattern of taste ratings seems to support the concept of 'hedonic-hunger' (Lowe & Butryn, 2007), that is, the drive to eat for pleasure in the absence of an energy deficit because the food has a high incentive value. The experienced pleasure of eating (palatability, unpleasantness) was significantly lower in the blindfolded group, as was the experienced refreshing quality of the ice cream. Not seeing the food might have decreased its incentive value, an idea that is corroborated by other studies showing that visual cues such as color play an important role in the eating experience (Jantathai, Sungsri-in, Mukprasirt, & Duerrschmid, 2014; Spence, Levitan, Shankar, & Zampini, 2010) and in the overall dining experience (Spence, 2010). The decrease in "visual flavor" in the blindfolded condition (Spence & Piqueras-Fiszman, 2012) might have decreased hedonic hunger and, consequently, approach behavior.

Throughout most of human history, the discrimination of edible and inedible food to avoid pathogens has been of primal importance (Cockburn, 1971; Wolfe, Dunavan, & Diamond, 2007). The robust elicitation of disgust when viewing spoiled and rotten foods is considered as an evolutionary adaptation for that purpose (e.g., Rozin & Fallon, 1987; Tybur, Lieberman, Kurzban, & DeScioli, 2013). Wansink and colleagues (2012) showed that ambiguous (difficult to discern or identify) food is also rated as less acceptable and willingness to consume it is lower. From an evolutionary perspective this is an adaptive response because such ambiguity could indicate an increased threat of ingesting pathogens (see also Tuorila, Meiselman, Bell, Cardello, & Johnson, 1994). In the present study, participants in the blindfolded condition were more surprised by and felt a greater need to get used to the ice cream's taste than the non-blindfolded group. These ratings are suggestive of increased perceived food ambiguity, which may have lowered its acceptability and the motivation to buy and consume it.

The findings regarding the reduced ability to monitor food intake when blindfolded shed new light on the effect of visual deprivation on intake perception. Both groups significantly overestimated the amount of ice cream they actually ate, which might mirror the 'bad calorie' effect, the tendency to overestimate calories of foods that are perceived as unhealthy (Oakes, Sullivan, & Slotterback, 2007, see also Chernev & Chandon, 2010; Wansink & Chandon, 2006). However, while this bad calorie effect might explain the general overestimation effect, it does not explain why overestimation differed between the two groups as indicated by the significant interaction term. Whereas the non-blindfolded group overestimated intake by 35%, the blindfolded group overestimated intake by 88%. Interestingly, the blindfolded group believed that they had eaten more ice cream than the non-blindfolded group when, in fact, their consumption was 9% lower. Visual deprivation thus caused a pronounced dissociation between actual and perceived intake. One might argue that the measurement of estimated consumption depends on visual information, thus it could be that the large differences are also due to the fact that it favors the non-blindfolded condition, limiting its validity (we thank an anonymous reviewer for this suggestion). However, it is important to note that the blindfolded participants systematically overestimated their intake rather than showing over- as well as underestimations (thus, just a greater variance in their estimations) which would have indicated that participants had estimation problems due to missing visual information causing disorientation. This pattern was not supported by the data, however; only evidence of systematic overestimation was found. Hence, not seeing the food particularly seems to shift the threshold for intake monitoring: smaller portions are sufficient to create the same intake feeling. This notion of a shifted or more 'conservative' intake monitoring threshold aligns with findings reported by Linné and colleagues (2002). They found that despite participants consuming a smaller amount of the test lunch meal when blindfolded, their reported feeling of fullness was identical to that reported after the meal consumed without blindfold. Although highly speculative, these results might indicate that vision deprivation increases perceived intake because the estimation of the satiating potential of foods (see Linné et al., 2002 and also Brunstrom & Rogers, 2009) depends more on 'real-time' experience than on prior expectations and thus 'remembered' experience (see Kahneman, 2011 and Robinson, 2014).

Alternatively, this dissociation between actual and perceived intake might be due to the fact that visual deprivation shifts attention to other senses. Research indicates that blind people show better odor discrimination and identification (Cuevas, Plaza, Rombaux, De Volder, & Renier, 2009) or superior tactile spatial acuity (Van Boven, Hamilton, Kauffman, Keenan, & Pascual-Leone, 2000) compared to sighted controls. The eating experience might thus have been more intense under the blindfold condition, leading to the observed overestimation effect (Spence & Piqueras-Fiszman, 2012). However, these findings might not be generalizable to people who are deprived of vision only for a few minutes. The dissociation might also be due to changes in the cephalic phase of digestion and neural mechanism in the brain involved in the termination of eating. Specifically, the sight of food facilitates the cephalic phase of digestion (Blundell, Hill, & Lawton, 1989), triggering salivation, insulin release, and gastric acid secretion, which in turn affect neural mechanisms (Barkeling et al., 2003; Linné et al., 2002, see also Simmons, Martin, & Barsalou, 2005; van der Laan et al., 2011) and the motivation for consumption.

Scheibehenne and colleagues (2010) also assessed perceived intake in a vision-deprivation study and, like in the current study, found that participants' ability to estimate their consumption deteriorated when eating blind. However, in their study, visual deprivation led to intake underestimation. This difference might be due to the type of eating situation (taste test vs. full meal) and the food being served (ice cream vs. lunch). Future studies might compare the effect of visual deprivation on the consumption of 'healthy' versus 'unhealthy' food as well as main meals versus snacks. Moreover, portion size as a normative cue (Herman & Polivy, 2008) might have been stronger in the lunch situation realized by Scheibehenne and colleagues (2010) as compared to the taste test paradigm utilized in the present study. Finally, the two eating situations probably differed with regard to whether participants had their eyes open or not. In the dining-in-the-dark restaurant participants probably ate with their eyes open while in the present study using modified ski goggles, participants probably had their eyes closed (see also Spence & Piqueras-Fiszman, 2012). Eyes-open and eyes-closed states in complete darkness differ consistently in the pattern of associated brain activation. Ocular motor and attentional systems are more activated when the eyes are open whereas the visual, somatosensory, vestibular, and auditory system are more activated when the eyes are closed (Marx et al., 2003; Wiesmann et al., 2006). Thus, closing one's eyes seems to induce a more interoceptive state of awareness characterized by greater multisensory activity while being in the dark, with the eyes open, induces an exeroceptive state of awareness with greater ocular motor activity and attention (Marx et al., 2003; Wiesmann et al., 2006).

4.1. Limitations

Limitations arise due to the specifics of the experimental procedure. A between-subjects design was chosen to prevent the inevitable order effects of a within-subject design. Hence, generalization is limited and great caution is needed when drawing conclusions for the real world (de Castro, 2000). Furthermore, confounding variables are of major concern. Importantly, control analyses secured the main findings with respect to potential confounding variables (hunger, outdoor temperature), but there might be other possible confounders that have not been considered. Moreover, the present study focused on one specific consumption situation in a student sample exposed to experimentally controlled eating conditions. Future research should examine the effects of vision deprivation across different types of food, meals, and situations (see also Sproesser, Kohlbrenner, Schupp, & Renner, 2015; Tăut, Renner, & Baban, 2012). For example, one may speculate that the present findings extend to other eating situations where unhealthy food items are consumed but not to eating situations with healthy food items.

Another potential limitation is in the method of assessing perceived consumption. For comparing actual and perceived intake as indicators of intake monitoring, both variables need to be measured on the same metric. As grams were used in previous studies to measure actual intake (see Scheibehenne et al., 2010), we opted for grams as the measurement unit. In order to calibrate estimation for all participants, we provided an anchor by stating that one spoon typically contains 9 g of ice cream (see methods section).

This measurement might have favored the vision condition since participants could see how full their spoons were each time (we thank an anonymous reviewer for this suggestion). Although we cannot exclude that the anchor may have been more useful in the vision condition, the slightly greater variance within the vision condition (*SE* = 23.6 g) than in the blindfolded condition (*SE* = 19.5 g) does not suggest a differential facilitation effect. In addition, if the method had facilitated a more accurate estimation in the non-blindfolded condition, the blindfolded condition should have been susceptible to greater estimation errors reflected in a greater range of estimations including over- and underestimations. Hence, the observed systematic intake overestimation might rather indicate a shift in the threshold for intake monitoring. However, future studies are needed replicating this research without providing such an anchor or by using alternative measures.

4.2. Conclusions and implications

The current study showed that depriving people of visual input affects food-related perception and behavior across four different response modes. Vision deprivation dissociated perceived consumption from actual consumption, with blindfolded participants overestimating consumption to a much larger extent than non-blindfolded participants. Vision deprivation also affected taste experiences and purchase willingness. Although results need to be replicated across different types of food and situations, as described above, these findings have two potential practical implications. First, they indicate that by removing sight it may be possible to shift the threshold for intake monitoring possibly by shifting attention toward 'interoceptive' cues of eating (Marx et al., 2003). This may provide unobtrusive and naturalistic means to change the experience of eating behavior. Another important implication of the finding that depriving participants from visual input dissociated their perceived from their actual eating behavior might be that common cognitive based navigation systems for the food environment such as dietary guidelines or nutrition facts which are primarily cognitive based and typically lack sensory information might actually create a fragile intake monitoring. Hence, one future perspective might be that we try to enrich the cognitive input with sensory input to facilitate normal eating.

Declaration of conflicting interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

Acknowledgements

We thank Bettina Ott and Tobias Flaisch for creating the audio questionnaire. We also thank Fee Benz, Kerstin Halbgebauer, and Angela Whale for their valuable support. This research was supported by a grant from the Federal Ministry of Education and Research (BMBF) (Grant 0315671, granted to Britta Renner & Harald Schupp). The funding body played no role in study design, in collection, analysis and interpretation of data, in the writing of the report, or in the decision to submit the article for publication.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.foodqual.2016.02.010.

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