

How do dogs monitor the human's attentional state after challenged by the presence of forbidden food?

Orsolya Kiss^{1,2} and József Topál¹

¹Institute of Cognitive Neuroscience and Psychology, Hungarian Academy of Sciences, Budapest, Hungary

²Department of Cognitive Science, Budapest University of Technology and Economics, Budapest, Hungary

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Introduction: Converging evidence suggests that the presence of (attentive) others has a positive effect on people's propensity to conform to social rules. It is also increasingly accepted that pet dogs are promising test subjects to study non-human analogues of "audience effect." This study investigates whether dogs show a tendency to change their behavior according to the visual attention of familiar and unfamiliar human partners in a situation in which human partners disallowed the dog from eating a piece of food. *Methods:* Dogs ($n = 64$) participated in two observational conditions (Attentive Owner and Attentive Experimenter) and a control condition in which both human participants engaged in distracting activity. *Results:* The results showed that the identity of the attentive or inattentive partner has little relevance to the dogs' gazing behavior (i.e., head orientation toward the different partners and the food) and their decisions about breaking or following the rule. This is in line with previous studies suggesting that the presence of the owner predominantly determines the dogs' responses to such situations. *Discussion:* Further analysis of dogs responding differently to the obedience challenge showed marked differences in the role of the "audience effect" might play in modulating "fully obedient," "ignorant," and "hesitating" dogs' gazing behavior. These findings point to the context-dependent nature of the audience effect in dogs and highlight the importance of frequently ignored individual differences in dogs' tendency to conform to the situational rules.

INTRODUCTION

Generally speaking, an *audience effect* arises when a subject's behavior changes in the presence of an attentive conspecific. Being watched by others has the potential to affect performance in various ways depending on task and context (Zajonc, 1965). It has been shown, for example, that arousal caused by the presence of others makes human participants perform better on easy tasks and worse on hard tasks (for a review, see Hamilton & Lind, 2016). Adolescents are particularly sensitive to the presence of peers when making risky and reward-related choices (Smith et al., 2014). Moreover, a stronger tendency to conform to prosocial norms has been reported in adult humans when they are in the presence of an observer (Brandt et al., 2003; Engelmann & Fischbacher, 2009; Nowak & Sigmund, 2005; Sylwester & Roberts, 2010) or even when subtle, "indirect" audience cues – such as images of watching eyes – are present (Bateson et al., 2006; Haley & Fessler, 2005; Nettle et al., 2013b; Powell et al., 2012). Preschool-age children's behaviors are also guided by reputational concern, and they selectively modify their behavior in the presence of a peer observer (Engelmann et al., 2013; Leimgruber et al., 2012; Shaw et al., 2014).

In the past few years, different cognitive frameworks have been proposed to account for audience effect in humans. These explanations presume some degree of consciousness (Bond, 1982), mentalizing (Hamilton & Lind, 2016), representation of self-concept, and the desire to make a positive impression on others (Ariely et al., 2009). However, we should note that sensitivity to others' visual attention, a core component of audience effect, does not necessarily imply higher-level cognitive processes. Infants, for example, are sensitive to whether someone is watching them from very early on; 1-year-olds modify their pointing behavior depending on the audience's attention and engagement in the task (Liszkowski et al., 2004) and toddlers take their partner's visual

Author for correspondence:

Orsolya Kiss

e-mail: kisorsolia@gmail.com

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attention into account when using referential gestures in a requesting paradigm (Marshall-Pescini et al., 2013).

Importantly, however, there is an apparent inconsistency between the human and non-human animal literature regarding the conceptualization of the audience effect. Namely, the audience effect in animal studies is generally used to refer the changes in the signaling behavior of individuals caused by the *mere presence* of other individuals (Coppinger et al., 2017). In line with this, a fundamental question for studying the audience effect in non-human animals is whether the observed changes in behavior indicate volitional control over signal production (e.g., more food calls when females are nearby than when males are present; Evans & Marler, 1994) or these are merely associated with arousal (Zajonc, 1965). Unfortunately, these investigations of “audience effect” in non-human animals have little, if any, relevance to studies in humans.

Some studies on non-human primates, however, showed that the audience effect is more than a “mere presence effect” (cf. social facilitation) and the signaler is sensitive to the receivers’ perceptual states, and modifies its signal use accordingly. Evidence suggests that non-human primate’s facial expressions can be mediated by the attentional states of an audience and that the signalers have some understanding of what others can (and cannot) see (Demuru et al., 2015; Leavens et al., 2010; Poss et al., 2006; Scheider et al., 2016; Waller et al., 2015). The production of facial expressions in orangutans (*Pongo* sp.), for example, is more intense and more complex during play when a recipient’s attention is directed toward them (Waller et al., 2015) and gibbons (*Hylobates* sp.) also tend to show facial expressions more often and over a longer duration when facing other individuals (Scheider et al., 2016). Although these results are insufficient to support the idea that primates have a deeper understanding of “being watched,” these clearly indicate that the production of facial expressions is not necessarily an automated response and subject to audience effects.

There are also studies investigating another important aspect of the audience effect, the reputational concern, in chimpanzees (*Pan troglodytes*). Nettle et al. (2013a) placed an image of a chimpanzee’s face above a food platform and measured subjects’ willingness to take preferred food. Chimpanzees did not show a robust and consistent behavioral change compared to a control condition in which a scrambled image was presented. Engelmann et al. (2016), however, found that the performance of chimpanzees (in a resource acquisition task) is affected by a spectator, but only if the conspecific observer is a potential competitor (i.e., chimpanzees worked to acquire more resources in the competition condition, but not in the mere presence of a passive observer). A co-performer also helps macaques (Stamm, 1961) and capuchins (Dindo & De Waal, 2007) when food is served as a reward for a cognitive task rather than being simply made available for consumption. However, the mere presence of a passive spectator produces the very same change: monkeys touch the images on the screen to obtain a food treat twice more often under “audience” and “co-action” condition than under “alone” testing (Reynaud et al., 2015). These mixed results further support the context-dependent nature of audience effect in primates,

and seem to correspond to the notion that, due to the competitive feature of non-human primate social life, competition with conspecifics could be especially effective in facilitating flexible cognitive skills (Hare & Tomasello, 2004) – including skills that promote audience effect.

The study of canine behavior offers unique, but yet not fully exploited possibilities to investigate audience effect in non-human animals. Increasing evidence indicate that domestic dogs (*Canis familiaris*) attend to a human’s attentional state and thus fulfill one of the core requirements of the audience effect. For example, after being told not to take a piece of food, dogs steal the food more often when the human turned back or engaged in distracting activity or the human’s eyes were closed compared to situations during which the human’s eyes were open while facing the dog (Call et al., 2003; Schwab & Huber, 2006). Bräuer et al. (2004) showed that dogs steal more pieces of forbidden food when they are hidden by a barrier completely while eating the food compared to the conditions where the barrier was not enough to block the human’s view of the approaching dog and/or the food. Moreover, dogs can take into account the level of illumination around the food (i.e., they steal more food when it is dark than when the area around the food is illuminated – Kaminski et al., 2013).

Dogs are also sensitive to the human’s attentional stance during communicative interactions with humans. They follow communicative gestures more when the human signaler’s eyes are visible and the gesture is clearly directed at them (Gácsi et al., 2004; Soproni et al., 2001), and they follow the gaze of a human to a target more readily when it is preceded by eye contact indicating the human’s communicative intent (Téglás et al., 2012). Others found that dogs and 2-year-old toddlers have similar capacity to take into account the attentional stance of the audience when initiating gaze shifts between a target and the human partner in different contexts (i.e., they increased their gaze alternation behavior when the task became unsolvable; Marshall-Pescini et al., 2013). Dogs also show some ability to take visual perspective of humans: they are capable of assessing the perceptual access of others, even if that differs from their own (Kaminski et al., 2009). Moreover, it seems that dogs’ facial expressions are subject to audience effects (i.e., they are more likely to produce facial gestures in the presence of an attentive human; Kaminski et al., 2017). These accumulating findings raise the possibility that dogs are able to form expectations about the audience’s attention and thus have a somewhat deeper understanding of “being watched” (Virányi et al., 2004).

We should also note that there is another important aspect of the audience effect in humans, that is, the specific effect of the relationship between the observer and the observed. It has been shown that the audience effect in adolescence depends on the identity of the spectator. That is, a friend (peer audience) as compared to an unfamiliar experimenter has stronger effect on participant’s performance (Wolf et al., 2015). Importantly, however, the question whether such effect on performance is dependent on the identity of the audience in the dog is still unanswered.

In this study, therefore, we explored the combined effects of familiarity and the attentional stance of human participants (audience) on dogs’ behavior in a “forbidden food”

situation. That is, dogs' willingness to obey the order of human partners (denying the dog from eating an otherwise obtainable piece of food) was investigated in three different audience conditions. In these conditions, the different human participants (the owner and an unfamiliar experimenter) either paid attention to the dog or engaged in distracting activity. We used a similar procedure of Call et al. (2003) with some specific changes discussed later in the experimental procedure and we predicted that dogs would be particularly sensitive to being observed by their caregiver relative to being observed by an unfamiliar human.

MATERIALS AND METHODS

Subjects

Sixty-four ($M_{\text{age}} = 4.40$, $SD = 2.84$ years, 32 males and 32 females from 31 different breeds and 19 mongrels) pet dogs and their owners were recruited on a voluntary basis from the Family Dog Research Database at the Department of Ethology, Eötvös University (Table 1). Only those dogs were included in the study that have been trained not to eat food using "leave it" (or some similar) command. We have also collected information about dogs' training prehistory via owner-report questionnaire. Nineteen dogs have not previously attended training classes (untrained dogs), whereas the others have completed basic obedience class ($N = 35$) or therapy dog training ($N = 10$).

Apparatus and experimental arrangement

The experimental trials were conducted either in a room (4.5×3.7 m) at the Department of Ethology, Eötvös Loránd University ($N = 29$ dogs), or in a room (4.5×5 m) at the Research Centre for Natural Sciences, Budapest ($N = 35$ dogs). Tests were video-recorded from four different angles using cameras fixed to the walls.

Procedure

The experimental procedure consisted of four different trials; a training trial – in order to make the dog familiar with the test situation – followed by 1–1 test trials in three different conditions ("Attentive owner," "Attentive experimenter," and "No audience" condition). The order of the conditions was counterbalanced across dogs.

Training trial. The owner (O) and the experimenter (E, author OK) were standing at their predetermined points in the middle of the room 0.5 m apart and facing each other while holding the same dish with four pieces of sausage on it. Before the experiment, the owners were asked what type of sausage their dogs liked and we used highly preferred food during the trials. O and E were talking to each other and pretending to eat while ignoring the dog for 30 s (Fig. 1a). During this period, the dog could explore the room freely. After 30 s, O and E placed the dish together on a low-height table (Fig. 1b), and they inhibited the dog from eating the food one after another (both O and E used the very same familiar command). Then, O and E took up their original

Table 1. Breed, age, and sex of dogs tested in the study

Nickname	Breed	Sex	Age (months)
Armin	Beauceron	Male	84
Beli	Cairn terrier	Female	37
Blöki	Golden Retriever	Female	17
Bodor	Mongrel	Male	141
Bodza_A	Samoyed	Female	25
Bodza_B	Mongrel	Female	15
Bodza_C	Labrador Retriever	Female	21
Bodza_D	Standard Schnauzer	Female	27
Bogyó	Mongrel	Female	66
Börni	Mongrel	Male	28
Borsó	Fox terrier	Female	42
Borzi	Bichon Havanese	Male	67
Bruno	Tibetan Spaniel	Male	104
Bubu	Mongrel	Male	57
Bukó	Border Collie	Male	113
Bunny	Border Collie	Female	139
Csele	Mudi	Female	72
Csipog	Mongrel	Male	99
Csutka	Puli	Female	41
Dió	Dachshund	Male	54
Döme	Wirehaired Vizsla	Male	12
Frida	Basset Hound	Female	33
Frúti	Mongrel	Female	92
Füge	Mongrel	Female	86
Gerzson	Hungarian Vizsla	Male	40
Happy	Labrador Retriever	Female	53
Hrunki	Pug	Male	105
Ifi	Airedale Terrier	Male	31
Izé	Chihuahua	Female	45
Jazz	Golden Retriever	Male	10
Kami	Mongrel	Female	104
Kifli	Hungarian Vizsla	Male	32
Leopold	Rough Collie	Male	14
Linzer	Hungarian Greyhound	Female	12
Luna	Labrador Retriever	Female	31
Mázli	Mongrel	Male	23
Milka	Border Collie	Female	69
Mixi	Mongrel	Female	45
Molly	Mongrel	Female	28
Mona	English Cocker Spaniel	Female	46
Muffin	Mongrel	Male	74
Mustár	Hungarian Greyhound	Male	16
Norbi	Mongrel	Male	46
Nyafi	Beagle	Female	108
Panka	Mongrel	Female	33
Patrik	Wirehaired Dachshund	Male	33
Pocak	Mongrel	Female	95
Prince	Golden Retriever	Male	48
Roxi1	Mongrel	Female	49
Roxi2	Bichon havanese	Female	58
Rudi	Wirehaired Vizsla	Male	35
Ryan	Border Collie	Male	40
Sába	American Staffordshire Terrier	Female	76
Sammy	Border Collie	Male	20
Sky	Mongrel	Male	10
Sneci	Wirehaired Dachshund	Male	22
Suti	Berger Blanc Suisse	Female	97

(Continued)

Table 1. (Continued)

Nickname	Breed	Sex	Age (months)
Szádor	Wirehaired Dachshund	Male	45
Szimpla	Border Collie	Male	12
Torma	Hungarian Greyhound	Female	16
Turmix	Border Collie	Male	77
Tuti	Mongrel	Male	100
Walter	Golden Retriever	Male	73
Zafi	Münsterlander	Female	13

position (facing each other) and talked to each other for another 30 s (Fig. 1c). Once the dog ate the food, E and O stopped talking and scolded the dog simultaneously in a familiar way (using the same words) while pointing to the empty dish. If the dog did not eat the food, they picked up the dish together and went back to their starting position. E replaced the food if it was necessary before starting the second phase.

Test trials. The three different types of test trials immediately followed the training trials.

Attentive Owner condition (N = 1 trial): The introductory phase of this trial consisted of the very same steps as in the training trial. But after placing the dish on a low-height table and inhibiting the dog from eating the food, O took his/her predetermined position facing the dog passively but constantly watching him, and E took her position in the corner of the room turning her back to the dog while engaging in a distracting activity (talking on a mobile phone) for 60 s. Neither E nor O interacted with

the dog during this time. After 60 s elapsed, both E and O approached the dish. They either scolded the dog simultaneously in a familiar way while pointing to the empty dish (if the dog ate the food) or just picked up the dish from the table. E replaced the food if it was necessary before starting the next trial (Fig. 2a).

Attentive Experimenter condition (N = 1 trial): The procedure was identical to that described in Attentive Owner condition, except that E and O changed their role. E was watching the dog silently, and O turned his/her back to the dog while engaging in a distracting activity (Fig. 2b).
No Audience condition (N = 1 trial): It started similarly to the previous two conditions, but after putting the dish on the table, both E and O turned their back to the dog, took their places in the corner of the room, and engaged in a distracting activity (talking on mobile phone) for 60 s (Fig. 2c).

The order of trials was counterbalanced across dogs.

Behavior coding and data analysis

Dogs were assigned into two categories: *Untrained* (N = 19) and *Trained* (N = 45) (see “Subjects” section). χ^2 test of homogeneity was used to determine whether the distribution of the *Trained* and *Untrained* dogs in the main response categories (*Obedient* – who did not take the food; *Disobedient* – who ate the food immediately or after some hesitation) is significantly different in the *Attentive Owner*, *Attentive Experimenter*, and *No Audience* conditions.

Dogs’ behavior was also analyzed using frame-by-frame coding of all experimental recordings with a 0.2-s resolution, using Solomon Coder (beta 091110, ©2006e 2008 by



Fig. 1. Photo illustration of the experimental arrangement (a–c: different steps of the training trial)

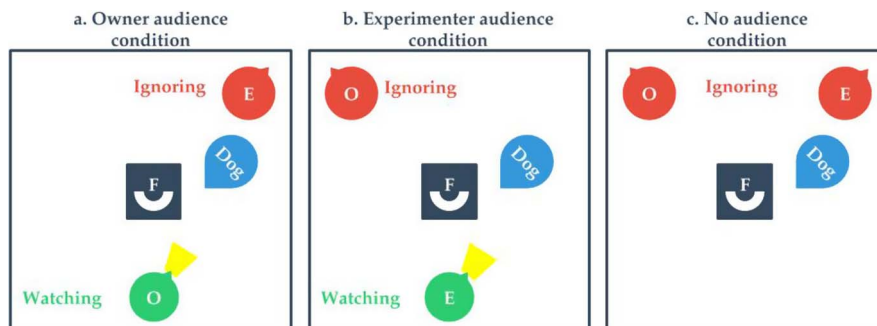


Fig. 2. (a–c) Experimental layout for the three different conditions, (a) the Attentive Owner condition when O was watching the dog and E was ignoring him, (b) the Attentive Experimenter condition when E was watching the dog and O turned his/her back, and (c) the No audience condition when both E and O were engaged in a distracting activity

András Péter, <http://solomoncoder.com/>). Interobserver agreement was assessed using parallel coding of 30% of the total sample by two trained observers. The following behaviors were coded:

- (1) Whether the subject took the food during the trial (Yes/No) (Cohen's $\kappa = 1.0$)
- (2) Latency to take the food (i.e., the time that elapsed between the moment the food was placed on the table and the moment the dog put its head into the dish, and touched the food). (percentage of interobserver agreement: 99%)
- (3) Relative durations (t%) of the head orientation toward the different directions (owner, experimenter, and food on the table) before (ORI_{before}) and after (ORI_{after}) eating the food. (percentage of interobserver agreement: 98.2%)

Related samples Cochran's Q test was used to compare dogs' tendency to take the forbidden food in the different conditions. Latencies to take the food in the different conditions were analyzed in Cox Model (R package "survival;" Therneau, 2015) with occurrence of eating as terminal event. Dogs that did not eat within 60 s were treated as censored observations [Attentive Experimenter: $N = 36$, Attentive Owner: $N = 33$, No Audience: $N = 32$ (of 64 censored dogs, respectively)].

Relative durations of dogs' head orientations before and after eating the food were analyzed with random intercept generalized linear mixed-effect models (GLMM; IBM SPSS 22, Armonk, NY): the model included two fixed explanatory variables: (a) the Condition (Attentive Owner, Attentive Experimenter, and No Audience) and (b) the Target of dogs' visual attention (Owner, Experimenter, and Table) as well as the two-way interaction of the above variables. Moreover, the dog ID (subjects' identity) as random factor was also included in the model, and non-significant effects were removed from the model in a stepwise manner (backward elimination technique).

Next, the head orientation data were reanalyzed (using the same GLMM as above) in three subgroups of the total sample separately: (a) those dogs were assigned to the "fully obedient" group, who did not eat the forbidden food during the 1-min trial. (b) "Hesitating" group included those subjects who disobeyed but hesitated some time before eating the food, and (c) those dogs were assigned to the "ignorer" group, who ate the food immediately (<1 s) after placing it on the table (i.e., they completely ignored humans' command).

RESULTS

χ^2 tests did not show significant differences between *Trained* and *Untrained* dogs' willingness to obey in the three different conditions [Attentive Owner: $\chi^2(1) = 1.581$, $p = .209$; Attentive Experimenter: $\chi^2(1) = 0.010$, $p = .917$; and No Audience condition: $\chi^2(1) = 1.581$, $p = .209$]. This finding supports that dogs' training prehistory plays a minor, if any, role in dogs' behavior observed in the forbidden-food situation.

Moreover, there were no significant differences between dogs' tendency to take the forbidden food in the different

conditions (Cochran's Q test, $p = .522$); $N = 28$ and 31 dogs (out of the 64) ate the food in the "Attentive Experimenter" and the "Attentive Owner" conditions and a similar proportion of subjects ($N = 32/64$) did so in the "No Audience" condition. Interestingly, more than one third of the subjects ($N = 24$) obeyed the command in all conditions (i.e., they never took the bait) and there were $N = 20$ consistently disobedient dogs (i.e., they ate the food in all conditions). The remaining 20 subjects showed "mixed" response, but they showed similar tendency to obey the command in different conditions (obedience rate: 60% in Attentive Experimenter, 45% in Attentive Owner, and 40% in No Audience conditions). Dogs' latency to take the food was also not affected by the condition [Cox Model, condition: $\chi^2(1) = 0.773$, $p = .679$, $\text{Exp}(\beta) = 1.1160$ (0.6695, 1.860)].

GLMM analysis of the duration of head orientation before eating the food showed that the target of visual attention had a significant main effect [$F_{(2, 402)} = 26.654$, $p < .01$]. That is, while hesitating whether or not to eat the forbidden food, dogs focused their attention predominantly on their owners. The Condition (i.e., the attentional stance of the Owner and Experimenter) showed no significant main effect [$F_{(2, 400)} = 0.130$, $p > .05$] on dogs' gazing behavior and there was no significant Condition \times Target interaction. However, after having eaten the forbidden food, neither of these factors [Condition: $F_{(2, 270)} = 1.355$, $p > .05$; Target: $F_{(2, 268)} = 1.176$, $p > .05$] had significant main effects on dogs' head orientation behavior, and there was no significant Condition \times Target interaction.

These results confirm the intuitively reasonable notion that dogs' gazing behavior in the phase of obeying (i.e., before eating the forbidden food) and in the phase of disobeying the command (i.e., after eating it) can be interpreted differently. In line with this, dogs were assigned to three types of response categories for further analyses: *fully obedient*, *ignorer*, and *hesitating* groups (see "Methods"). The majority of subjects ($N = 32$ in the "No Audience," $N = 36$ in the "Attentive Experimenter," and $N = 33$ in the "Attentive Owner" conditions) did not eat the bait during the 1-min waiting period. The remaining ones either ate the food right after it was placed on the table ($N = 21$ dogs in the "No Audience" and $N = 18$ – 18 in the "Attentive Experimenter" and "Attentive Owner" conditions) or ate it after some hesitation ($N = 11$ in the "No Audience," $N = 10$ in the "Attentive Experimenter," and $N = 13$ in the "Attentive Owner" conditions).

GLMM analysis of the *fully obedient* group showed that the Target of visual attention had a significant effect on the duration of dogs' head orientation [$F_{(2, 300)} = 33.892$, $p < .01$], while there was no significant main effect of the Condition [$F_{(2, 298)} = 0.037$, $p > .05$], and there was no Condition \times Target interaction. The post-hoc pairwise analyses show that dogs gazed significantly longer at their owners (owner vs. experimenter, $p < .001$ and owner vs. table, $p < .001$) and they tended to look longer at the unfamiliar experimenter than toward the food (experimenter vs. table, $p = .042$) (Fig. 3).

Dogs' visual attention in the *hesitating* group (i.e., they were disobedient after some hesitation, mean latency of eating: 13.3 s, range: 1–46.8 s) was analyzed separately in the "obedient" and "disobedient" phases of the trials, that is,

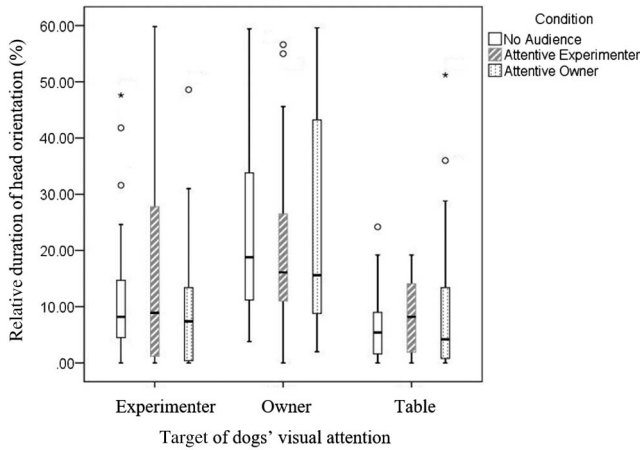


Fig. 3. Fully obedient dogs’ visual attention toward the different targets. The medians of data are represented by bold lines, and boxes indicate the 50% of the data (lower and upper interquartile range). Whiskers extend to the smallest and largest values excluding outliers

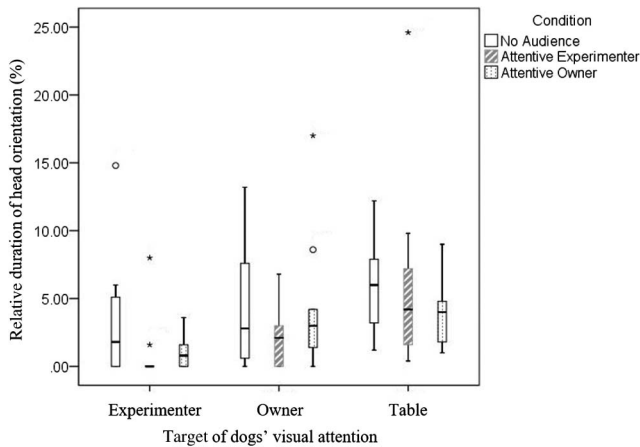


Fig. 4. Dogs’ visual attention toward the different targets in the *Hesitating* group during the “obedient” phase of the trial (i.e., before eating the food). The medians of data are represented by bold lines, and boxes indicate the 50% of the data (lower and upper interquartile range). Whiskers extend to the smallest and largest values excluding outliers

before and after eating the forbidden food. The GLMM analysis of these dogs in the “before eating” phase showed a significant main effect of the target of visual attention [$F_{(2, 99)} = 7.839, p = .001$], but there was no significant effect of Condition [$F_{(2, 97)} = 1.952, p > .05$] and the interaction effect was also non-significant. The post-hoc pairwise analyses indicate that, unlike *fully obedient* dogs, subjects of the *hesitating* group mostly paid attention to the food (table vs. experimenter, $p < .01$; table vs. owner, $p = .084$) and they also gazed more at their owners than the unfamiliar experimenter (owner vs. experimenter, $p = .030$) (Fig. 4).

Interestingly, however, the GLMM analysis of these dogs’ head orientation in the “disobedient” phase (i.e., after eating the forbidden food) showed a significant Target \times Condition interaction effect [$F_{(4, 93)} = 3.443, p = .011$] while the main effects of Target [$F_{(2, 93)} = 0.016, p > .05$] and Condition

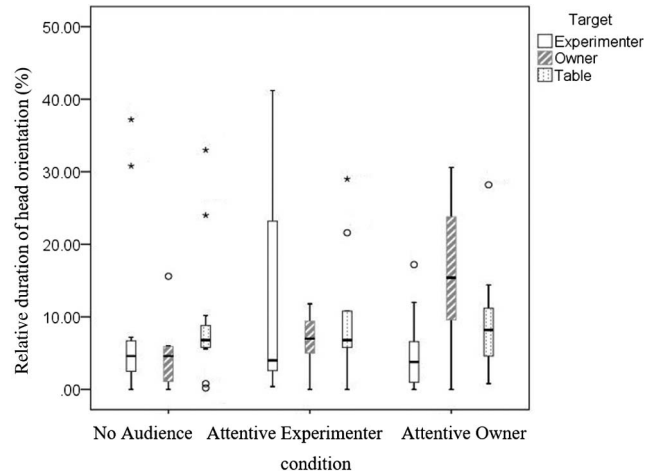


Fig. 5. Dogs’ visual attention toward the different targets (experimenter, owner, and table) in the *Hesitating* group during the “disobedient” phase of the trial (i.e., after eating the food). The median of data are represented by bold lines, and boxes indicate the 50% of the data (lower and upper interquartile range). Whiskers extend to the smallest and largest values excluding outliers

[$F_{(2, 93)} = 0.696, p > .05$] remained non-significant. In order to understand this interaction effect better, we analyzed the three different audience conditions separately and found that dogs divided their attention among the potential targets (owner, experimenter, and table) differently only when the owner was the spectator (Attentive Owner condition). Dogs oriented significantly longer toward their owners than toward the experimenter or the table in this condition [owner vs. experimenter: $t_{(36)} = 3.567, p = .001$; owner vs. table: $t_{(36)} = 3.019, p = .029$; experimenter vs. table: $t_{(36)} = -1.289, p = .205$] (Fig. 5).

Dogs of *ignorer* group did not pay increased attention to the potential targets in the different audience conditions as there were no significant main effects of Target [GLMM, $F_{(2, 168)} = 1.438, p > .05$] and Condition [$F_{(2, 166)} = 0.886, p > .05$], and there were no significant interaction between these factors.

DISCUSSION

In this study, we investigated whether dogs show a tendency to change their behavior according to the visual attention of familiar and unfamiliar human partners in a situation in which human partners disallowed the dog from eating a piece of food. Dogs participated in two types of observational conditions (Attentive Owner and Attentive Experimenter) and a control condition in which both human participants turned their back and engaged in a distracting activity (No Audience condition).

Ample evidence suggests that dogs are sensitive to behavioral cues indicating attention (body posture, head orientation, and visibility of the eyes). Surprisingly, however, our results show that dogs’ willingness to obey was unaffected by changes in either their owner’s or an unfamiliar human’s attentional state and this may suggest that dogs were insensitive to the focus of human visual attention

in this particular situation. This finding is in line with the study of Schwab and Huber (2006) that has demonstrated in a similar situation that the rate of obedience (i.e., proportion of trials in which the dogs obeyed the command) was not affected by the owners' visual attention. Simultaneously, this is not congruent with the findings of other previous studies (Call et al., 2003; Kaminski et al., 2013), in which dogs were more likely to take the forbidden food when the unfamiliar human experimenter could not see them. However, it is noteworthy that dogs were left alone for a relatively long time in these studies (180 s in Call et al., 2003 and 120 s in Kaminski et al., 2013) and the food bait was placed on the floor. We may assume that dogs find food on floor more tempting (than food on a table) – especially when they are alone – because owners typically do not allow their dogs to eat off the table. In line with these, all dogs in Call et al.'s (2003) study picked up the forbidden food from the floor at least once even when the human was watching them, whereas in our experiment more than one third of subjects (37.5%) never touched the food. Hecht et al. (2012) reported comparable results in a similar paradigm (36.2% of dogs did not eat forbidden food from the table). Accordingly, the lack of context-dependent changes in dogs' willingness to obey in this study may be because (a) dogs were never left alone and (b) forbidden food on the table was less tempting to them. Another key aspect of our experimental procedure relates to the timing of verbal feedback (scolding the “disobedient” dog). Unlike in other studies (Bräuer et al., 2004; Call et al., 2003; Kaminski et al., 2013; Schwab & Huber, 2006) in which the experimenter did not react to the dog's actions, both the owner and the experimenter in this study scolded the dog for taking the food.

More importantly, subjects in all conditions (Call et al., 2003; Kaminski et al., 2013) or at least in some trials (Schwab & Huber, 2006) were observed without their owners being present whereas the owner of the dog was present throughout the trials in our experiment. We used this procedure because we wanted to avoid the emergence of stress-related behaviors in dogs evoked by separation from their owners. Ample evidence indicates that most pet dogs are likely to show signs of separation anxiety when left alone or when only an unfamiliar experimenter is present (see Topál & Gácsi, 2012 for a review). In such “obedience tasks” separation-related distress can be a potential confounder that may modulate decision-making in dogs, increasing or suppressing dogs' desire to eat (Schwartz, 2003). Based on previous findings, it seems therefore reasonable to assume that the lack of context-specific differences in dogs' willingness to obey was not due to dogs' inability to perceive the focus of human visual attention, but at least partly because there were no changes from trial to trial in dogs' anxiety and thus there were no changes in their desire to consume the forbidden food.

An intriguing and previously unexplored aspect of dogs' behavior in “forbidden food” tasks is the relationship between the human observer and the dog. Our results clearly showed that, contrary to our expectations, dogs' social relationship with the visually attentive human partner (owner vs. unfamiliar experimenter) had no additional effect on their willingness to obey. This finding provides the possibility that the mere presence of the owners during trials is a

robust factor that overrides the effect of changes in audience familiarity. In other words, the presence of the owner predominantly determines the dogs' behavior and the identity of the attentive or inattentive partner has little (if any) relevance to the dogs' decisions about breaking or following the rule. The effect of “mere presence” on dogs' decision-making seem to correspond with human studies, suggesting that the physical presence of an inattentive partner (i.e., the mere possibility of social interaction) can alter adult participants' social attention and thus sufficient to affect their behavior in task situations (Kaitlin et al., 2011).

The analysis of the direction of dogs' visual attention (head orientations) provides a somewhat more refined picture of decision-making processes underlying dogs' behavior in this situation. Interestingly, dogs paid attention to their owners and the unfamiliar experimenter differently only before breaking the rule. They preferred to look at their owner only during the “hesitation phase” of the trial independently from their owners' attentional stance. This result suggests that dogs await further instructions from their human caregiver on how to act, or they simply monitor whether the owner is paying attention. Anyway, this finding further supports our notion that dogs preferably rely on owner-given cues when making a decision about whether to obey or disobey.

The elimination of preferential attention to owner over experimenter in the “after eating” phase of the trials, however, indicates that attentional bias cannot be considered as a behavior associated with disobedience in dogs (cf., guilty look – Hecht et al., 2012).

The analyses of subgroups responding differently to the obedience challenge (“fully obedient”; “ignorant”; “hesitating”) shed light on further interesting findings. Dogs who ate the food immediately after placing it on the table (“ignorant” subgroup) not only totally ignored humans' command but they were completely insensitive to the presence of familiar and unfamiliar humans showing different visual attention. This is so because individual differences in dogs' reward responsiveness, including motivational differences to obtain the reward, might also have an effect on dogs' obedience. Personality correlates of increased reward responsiveness in dogs (inattention and hyperactivity-impulsivity; Gerencsér et al., 2018) can cause a sudden and “unthought” response (getting the reward), without paying attention to the audience or other contextual information.

In contrast, dogs of “fully obedient” subgroup focused their attention toward their owners throughout the trial either because they were waiting for their owners' permission independently from his/her attentional focus, or because they expect a piece of reward from the owner (in such situations, owners often reward their dogs for obeying the “leave it!” command by giving it another piece of food). Importantly, the gazing behavior of “hesitating” dogs appeared to be much more sensitive to the contextual changes. First, unlike other dogs, they initially preferred to watch the food (this may indicate that the dog is struggling with temptation) while also looking toward the owner more than the experimenter. Second, after violating the rule (eating the forbidden food), the dogs of “hesitating” subgroup continued to display a significant attention bias toward their owners but only in those trials in which

their owners were visually attentive (i.e., Attentive Owner condition). The finding that these dogs were sensitive to their owners' attentional stance may reflect intriguing differences between the two subgroups of disobedient dogs (i.e., "ignorant" vs. "hesitating" subjects). Namely, the gazing behavior of hesitating dogs – after having eaten the forbidden food – may be interpreted as apprehensive behavior (worrying about disobedience) or as a so-called "guilty look" (Hecht et al., 2012) that may reflect subjects' fear (expectation) of being punished. It is noteworthy that Hecht et al. (2012) in their study did not find significant differences in the emergence of associated behaviors of "guilt" between dogs that broke the rule and ate the forbidden food in owners' absence and dogs that did not.

These results provide further support for the notion that dogs, while being faced with an obedience challenge, perform different visual monitoring strategies in the presence of their caregiver and an unfamiliar observer. Our findings also point to the context-dependent nature of audience effect in dogs and highlight the importance of frequently ignored individual differences in dogs' tendency to conform to the situational rules.

CONCLUSION FOR FUTURE BIOLOGY

Susceptibility to the audience effect is a "building block" of the wide array of social features that make human social cognition unique. Although there are some clear parallels between human and non-human social behaviors including sensitivity to the audience, comparative research efforts suffer from both conceptual inconsistencies and methodological shortcomings. The domestic dog is a promising candidate species for studying non-human analogues of "audience effect" because, among others, they are highly sensitive to the attentional state of humans, and simultaneously, demonstrate an exceptional willingness to conform to the expectations and instructions of an "authority figure." This study, in line with previous research, further supports the notion that pet dogs are susceptible to audience effect. In contrast to previous studies, however, we have provided novel insights into dogs' sensitivity to human audience, demonstrating that there are characteristic differences between individuals in terms of the readiness to conform to the human expectations. Moreover, these differences are likely to be associated with differences in cognitive processes underlying sensitivity to audience and/or motivational differences in obtaining food reward. Although the reason for this individual variability in decision-making is not well understood, future studies should take these potential differences into consideration when studying complex social cognitive phenomena such as audience effect. In summary, we think that comparative investigation of the audience effect can be (and should be) put in a broader perspective, which will help us gain a better understanding of the evolutionary origins of human social cognition.

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