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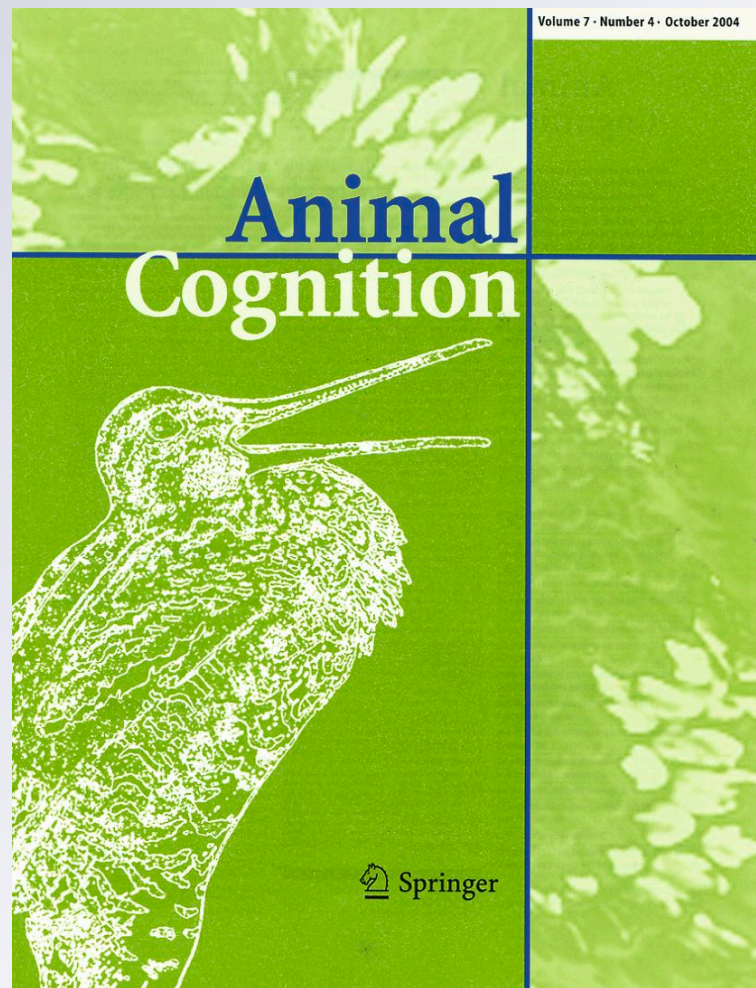
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Does the A-not-B error in adult pet dogs indicate sensitivity to human communication?

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Abstract Recent dog–infant comparisons have indicated that the experimenter’s communicative signals in object hide-and-search tasks increase the probability of perseverative (A-not-B) errors in both species (Topál et al. 2009). These behaviourally similar results, however, might reflect different mechanisms in dogs and in children. Similar errors may occur if the motor response of retrieving the object during the A trials cannot be inhibited in the B trials or if the experimenter’s movements and signals toward the A hiding place in the B trials (‘sham-baiting’) distract the dogs’ attention. In order to test these hypotheses, we tested dogs similarly to Topál et al. (2009) but eliminated the motor search in the A trials and ‘sham-baiting’ in the B trials. We found that neither an inability to inhibit previously rewarded motor response nor insufficiencies in their working memory and/or attention skills can explain dogs’ erroneous choices. Further, we replicated the finding that dogs have a strong tendency to commit the A-not-B error

after ostensive-communicative hiding and demonstrated the crucial effect of socio-communicative cues as the A-not-B error diminishes when location B is ostensibly enhanced. These findings further support the hypothesis that the dogs’ A-not-B error may reflect a special sensitivity to human communicative cues. Such object-hiding and search tasks provide a typical case for how susceptibility to human social signals could (mis)lead domestic dogs.

Keywords Dog · A-not-B error · Social cognition · Communication

Introduction

After repeatedly obtaining a target object hidden at one location (A), 8- to 12-month-old infants continue to search for the object at the same location despite having just seen the object being hidden at a new place (B). This phenomenon is called the A-not-B error, one of the most consistently replicated phenomena in developmental psychology (Piaget 1954). Although the standard Piagetian A-not-B error task was traditionally conducted in an inherently interactive situation, the traditional interpretations did not account for the effect of the hider’s communicative behaviour on the infants’ perseverative searches (Wellmann et al. 1987). A recent study (Topál et al. 2008), however, showed that infants’ A-not-B error is triggered largely by the ostensive-communicative cues given by the experimenter (eye contact, gaze shift, addressing). This finding, in line with the ‘natural pedagogy’ account (Csibra and Gergely 2009), suggests that infants commit the error in the B trials because they misinterpret the model’s communicative object-hiding actions in the A trials as

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'teaching' and generalize the information received in the A trials also to the B trials. Consequently, the error is much reduced if the object is hidden in the absence of human communicative cues (both after non-communicative, but social, and after non-social hiding).

Interestingly, it was found that adult pet dogs also commit the A-not-B error more often after seeing the object being hidden in the presence of ostensive-communicative cues of the experimenter (Topál et al. 2009). However, the exact nature of dogs' responsiveness to human communicative signals and its role in inducing the perseverative search error are still unknown (Tomasello and Kaminski 2009). Accordingly, an ongoing debate discusses whether the errors made by dogs are caused by similar processes as in infants or whether simpler learning processes or confounding effects of procedural factors can account for them (Fiset 2010; Marshall-Pescini et al. 2010; Topál et al. 2010). In the current paper, we address questions related to these alternative hypotheses.

Study 1

Background

Fiset (2010) argues that, independently from the presence of ostensive-communicative cues, the A-not-B error made by dogs can be caused by the fact that during the B hidings, instead of moving on a straight route, the reward is following a roller-coaster trajectory visiting first location A and only then B. This 'sham-baiting' of the A location in the B trials raises the possibility of strong proactive interference increasing the chance that dogs mix up earlier memory traces of the toy being at location A in the A trials with the more recent input of seeing the toy disappearing at location B in the B trials (see e.g. Hartshorne 2008). In infants it has been shown that they reliably reach back to location A even though they saw that the object went straight to the B hiding place without getting in contact with A, discounting this alternative hypothesis as a reason for the A-not-B error (e.g. Gratch et al. 1974; Diamond 1985). In order to examine whether the attentional demands of this distractive component of the hiding contributed to the dogs' A-not-B error in Topál et al. (2009), we tested whether dogs show a reduced tendency to commit the A-not-B error if location A is not sham-baited in the B trials.

Another argument, as often suggested in infant studies (e.g. Smith et al. 1999), is that subjects may commit the error in the B trials because they cannot inhibit the prepotent motor behaviour of searching at location A after doing so several times in the A trials. This alternative mechanism has also been called into question, because

infants even after performing no motor response in the A trials but only passively observing the A hidings perseverated in the B trials (Longo and Bertenthal 2006). Again, this hypothesis has not yet been tested in dogs. Thus, in a second group of dogs, by modifying the ostensive-communicative hiding procedure of Topál et al. (2009), we examined whether dogs commit fewer errors if they only watch repeated hidings at location A but are not allowed to search there actively.

Materials and methods

Subjects

Adult pet dogs ($N = 94$) from 27 different breeds participated in the study (males/females: 51/43; mean age: 4.3 ± 2.4 years). They were assigned to three different groups quasi-randomly so that the distribution of age and gender did not differ across groups. Fourteen dogs were excluded from the experiment either because they failed to fulfil the criteria in the pre-training trials ($N = 9$), lost interest in the task in midstream ($N = 3$) or their owners disobeyed the experimenter's instructions ($N = 2$).

Experimental arrangement

The experiments took place in a room (6.3 m \times 4.8 m) at the Clever Dog Laboratory, Vienna, where two opaque plastic screens (30 cm wide \times 50 cm high \times 30 cm deep with a wooden box fixed on the back side) were placed 0.6 m apart to hide the toy. The owner held the collar of the dog that was facing the screens standing equidistant (2 m) from them. A rubber toy was placed on the floor 0.6 m from the left or the right screen (counterbalanced across dogs) in line with the screens.

Procedure

Before the test trials, subjects participated in two warm up trials. In these trials, only one screen was placed on the floor and the experimenter placed the toy behind it in full view of the dog that was then released to search for it. Animals were included in the next phase only if they did not show any sign of distress and were motivated to fetch the toy.

Test trials consisted of 4 A and 3 subsequent B trials. Depending on the group they were assigned to, subjects witnessed one of three different hiding procedures.

In the *Communicative Hiding* group (*Com-H*, $N = 20$), we aimed to reproduce earlier findings and therefore we applied the same procedure reported in Topál et al.'s study (2009). During the A trials, the experimenter addressed the

subject (dog's name + 'Look!' in a high-pitched voice), she approached the toy, picked it up and captured the dog's attention with the toy in hand (by establishing eye contact and addressing the dog). Then she walked to the adjacent screen (A) and placed the toy behind it. Finally, after walking behind screen B, the experimenter returned to the dog that was released by the owner. If the subject chose the baited screen, it was praised and allowed to play with the toy for a few seconds. If the subject visited the empty screen first, it did not get the toy but was called back and praised verbally by the owner. The whole procedure was repeated three more times.

Immediately after the four A trials, three B trials followed. These were similar to the A trials, except that the experimenter did not leave the toy behind screen A, but instead the toy visibly re-emerged in her hand and she showed the toy to the dog while looking at it. Then she placed the toy behind screen B and returned to the dog, which was allowed to make a choice (Video S1).

Testing a second group of dogs, the so called *Alleviated B trials* group (*Allev-B*, $N = 34$) we aimed to control for the 'sham-baiting' that occurred in the B trials of the *Com-H* procedure. In this condition, dogs witnessed the same hiding procedure as dogs in *Com-H*, with the only exception that during the B trials, the experimenter did not 'sham bait' the toy behind screen A. She walked up to screen B following the same track as in the *Com-H*, while holding the toy visibly in her hand at the height of her eyes and looking continuously at the dog (Video S2).

In the *Only watching during A trials* group (*Watch-A*, $N = 26$), we aimed to investigate the effect of the motor response in the A trials. Therefore, the procedure used in this condition was the same as in *Com-H* except that subjects were not allowed to search for the toy in the A trials. Instead, after having arrived at the location close to the dog, the experimenter pulled out the toy remotely from behind screen A by a string fixed to the ball. After the toy had been retrieved in this way, the dog was allowed to play with it for a few seconds without leaving its place. In the B trials, subjects were allowed to search for the toy as in *Com-H* (Video S3). All tests were videotaped for later analysis.

Data analysis

In all groups, the first location inspected was regarded as the subject's choice. A choice was scored if the dog touched the screen with its nose or paw. Dogs received scores of 1 or 0 depending on whether they chose the baited or the empty location, respectively. In a very few cases (5 trials out of 456), the dogs made an ambiguous choice (they passed along the midline between the screens having equal visual access to the content of both hiding places and made

their choice only afterwards); these trials were excluded from the analysis.

Within each group, the per cent of correct choices in the three B trials, and the choice in the first B trial, was compared to the 50 % chance level using a one-sample Wilcoxon signed-rank test and a binomial test, respectively. Furthermore, planned pair-wise comparisons between the *Com-H* and the modified conditions (*Allev-B* and *Watch-A*, respectively) were performed (Mann-Whitney tests).

Results and discussion

Dogs fetched the object reliably from behind screen A during the A trials, choosing the empty screen only twice out of 216 trials. During the B trials, however, subjects displayed perseverative search bias to the empty (A) location performing well below the success rate expected by random search (one-sample Wilcoxon Signed-rank tests) not only in the *Com-H* (23 % correct, $T = 174$, $p = 0.0083$) but also in the *Allev-B* (25 % correct, $T = 488$, $p = 0.0007$) and *Watch-A* (24 % correct, $T = 288$, $p = 0.0032$) groups (Fig. 1a).

Choice behaviour in the first B trials (Binomial test, test proportion: 0.5) showed a similar below chance performance in the *Com-H* ($p = 0.008$), *Allev-B* ($p = 0.001$) and *Watch-A* ($p = 0.001$) conditions.

Planned pair-wise comparisons (Mann-Whitney tests) of the subjects' performance in the B trials between *Com-H* and the modified conditions failed to show any effect of 'sham-baiting' in the B trials (*Com-H* vs. *Allev-B*; $U = 336$, $p = 0.937$) as well as of actively searching in the A trials (*Com-H* vs. *Watch-A*; $U = 250$, $p = 0.803$).

In sum, we found that dogs tended to commit the A-not-B error even though the situation was attentionally less demanding when no 'sham-baiting' occurred in the B trials. Furthermore, subjects also showed a perseverative response pattern in B trials if they did not have the possibility to actively search in the preceding A trials. Based on these results, we can conclude that neither an inability to inhibit previously rewarded motor response nor insufficiencies in their working memory and/or attention skills can explain dogs' erroneous choices.

Study 2

Background

In Study 1, we found indirect support for the claim that dogs commit the A-not-B error due to the human experimenter's ostensive cues by excluding two alternative

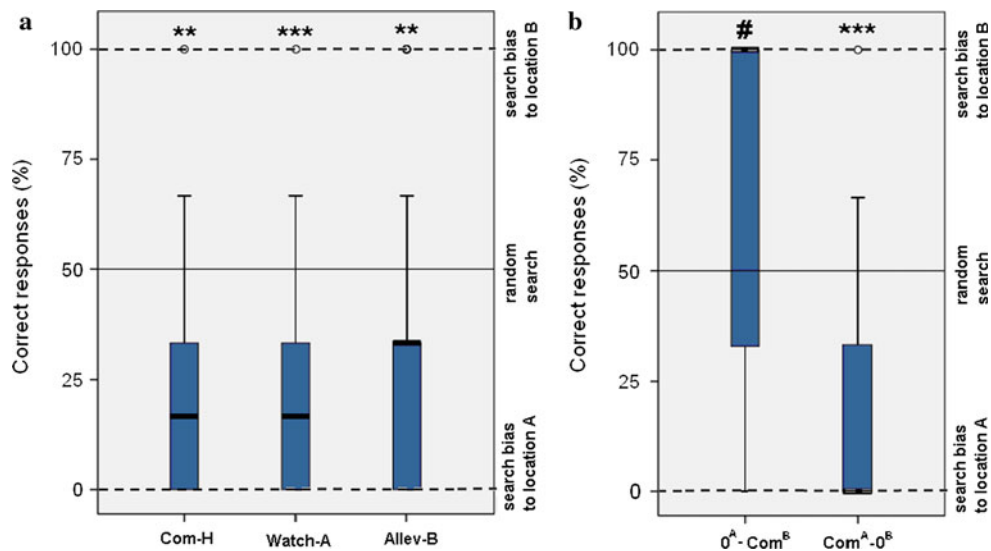


Fig. 1 Per cent of correct responses (median, quartiles and extremes) in the 3 B trials as a function of the hiding procedure. One-sample Wilcoxon signed-rank test; # $p < 0.1$, ** $p < 0.01$, *** $p < 0.001$ in comparison with success rate expected by random choice (50 %). **a** In the *Com-H* group, screen A was sham-baited just like in Topál et al.

(2009). In *Watch-A* group, the dog was just a bystander during the A trials. In *Allev-B* group, screen A was not revisited by the experimenter during the B trials. **b** Ostensive-communicative cues (eye contact and addressing) in the B trials were given only at location B in 0^A-Com^B group and only at location A in $\text{Com}^A\text{-}0^B$ group

hypotheses that have been previously proposed. In Study 2, we aimed to directly investigate the effect of ostensive-communicative cues on dogs' search behaviour in the same A-not-B error task. The original study by Topál et al. (2009) tested the crucial role of dogs' susceptibility to human communicative signals in an A-not-B search error task by consistently manipulating the communicative aspect of the hiding procedure in both the A and B trials. In one condition, they hid the reward in a non-social manner (the ball was moved around using an invisible string attached to it), and in this case, most dogs succeeded in finding the hidden object without making the A-not-B error. They also tested dogs in social conditions, in which a human experimenter carried the ball around after calling the dogs' attention in both the A and B trials either in an ostensive (addressing the dogs by saying 'Dog's name+Watch!' and making eye contact with it) or in a non-ostensive (squeezing the toy) manner. Perhaps the most interesting finding of this study was that, although in both social conditions the toy was hidden by a human experimenter, dogs committed the A-not-B error more frequently in the ostensive condition as compared to the non-ostensive one. These findings suggested that dogs' response to human communication is primarily driven by a motivation to satisfy ostensibly cued human imperatives even when it leads to an inefficient or mistaken solution. However, as pointed out by Tomasello and Kaminski (2009), in the original *Com-H* condition, the experimenter not only addressed the dog ('Name+Watch!' and eye contact) at the A hiding place, but also gave some ostensive

cues (eye contact) before hiding the object in location B. Although communicative, dogs did not follow these limited ostensive cues directed to location B, suggesting that dogs acquire generic information during the A trials and tend to rely on this knowledge when making their choice in the B trials (see also Topál et al. 2010). Alternatively, one can argue that dogs' erroneous choices in the B trials are caused by the current signals provided by the experimenter.

In accordance with the latter argument, assuming that eye contact has less influence on dogs compared to a combination of different ostensive cues ('Dog's name+ - Watch!', high-pitched voice and eye contact), it can be assumed that dogs will prefer the better enhanced A location over location B as shown in the original *Com-H* condition. This latter hypothesis has been confirmed by Marshall-Pescini et al. (2010) who found that, after being addressed ostensively ('Dog's name+Watch!' and eye contact) at both the A and B locations, dogs are no longer biased toward location A and make fewer erroneous choices. This procedure, however, differed from the 'Com-H' condition (both in the original study by Topál et al. 2009 and in the present study) not only in the distribution of ostensive cues in the B trials but also in that the experimenter did not return to the initial position after the hiding procedure, but stayed adjacent to the dog and its owner at the B side, possibly attracting the dogs to location B (Marshall-Pescini, personal communication).

Therefore, in order to investigate to what extent the presence of ostensive cues in the B trials next to location A and B influences the A-not-B error of dogs, we tested 2

additional groups of dogs. The A trials were identical to the *Allev-B* group while 2 extreme versions of the B trials were applied when either only location A (*Communicative cues only next to A* group— Com^A-0^B) or only location B (*Communicative cues only next to B* group— 0^A-Com^B) was highlighted by the experimenter's ostensive cues. In the former group, dogs may be driven to choose location A in the B trials by the experimenter's imperatives received in the A trials as well as during the recent hiding procedure of the B trials, whereas in the latter group, the experimenter's earlier and recent ostensive cues suggest conflicting choices. Consequently, if the choice of dogs in the B trials varies according to cues given by the experimenter during the preceded hiding, we expect them to choose location B in this group. If, however, dogs commit the A-not-B error because in the B trials they tend to follow the imperatives the experimenter communicated to them in the A trials, they should choose location A in the latter group. In order to eliminate all other factors that may remind dogs of the former A trials, location A was not sham-baited in the B trials. That is, the hiding procedure was the same as on the *Allev-B* group in Study 1.

Materials and methods

Subjects

Adult pet dogs ($N = 37$) from 14 different breeds participated in the study (males/females: 23/14 and mean age: 4.4 ± 3.4 years). They were assigned to two different groups quasi-randomly so that the distribution of age and gender did not differ across groups. None of the subjects had to be excluded from the study.

Experimental arrangement

The experiments took place in a room (3.9 m \times 4.1 m) at the Eötvös University, Budapest, where two opaque plastic boxes (30 cm wide \times 50 cm high \times 30 cm deep) were placed 0.6 m apart to hide the toy. The owner held the collar of the dog that was facing the screens standing equidistant (2 m) from them. A rubber toy was placed on the floor 0.6 m from the left or the right screen (counter-balanced across dogs) in line of the screens.

Procedure

Before the test trials, subjects participated in two warm up trials where only one screen was placed on the floor using the same procedure as in Study 1. Test trials again consisted of four A and three subsequent B trials. Depending on the group they were assigned to, subjects witnessed one

of two different hiding procedures. The dogs in both groups watched the same hiding as in the *Allev-B* condition of Study 1, with modified B trials involving ostensive-communicative cues (addressing and eye contact) only next to location B (*Communicative cues only next to B* group— 0^A-Com^B , $N = 18$) or only next to A (*Communicative cues only next to A* group— Com^A-0^B , $N = 19$) (Video S4, S5).

Elimination of the 'sham-baiting' to the A hiding place during the B trials (*Allev-B*) did not have an effect on the dogs' performance (compared to the original *Com-H* condition)—see above. However, in order to prevent any possible interactions between the higher demands on working memory (caused by the 'sham-baiting') and other factors to be tested, we decided to modify the *Allev-B* condition instead of the *Com-H* condition.

Data analysis

Data analyses were carried out in exactly the same way as in Study 1 with comparisons to the 50 % chance level (Wilcoxon signed-rank test, Binomial test) and planned pair-wise comparisons to the original *Allev-B* group (Mann–Whitney test). Only one out of the 259 trials was excluded due to ambiguous choice.

Results and discussion

Dogs fetched the object reliably from behind screen A during the A trials, choosing the empty screen only once in 148 trials. During the B trials, subjects displayed perseverative search bias to the empty (A) location performing well below the success rate expected by random search (one-sample Wilcoxon Signed-rank tests) in the Com^A-0^B (18 % correct, $T = 173.5$, $p = 0.0006$) group. In contrast, dogs in the 0^A-Com^B group showed a trend towards above-chance performance (69 % correct, $T = 45$, $p = 0.0814$) (Fig. 1b). Choice behaviour in the first B trials (Binomial test, test proportion: 0.5) showed a similar below chance performance in the Com^A-0^B ($p = 0.019$) condition and chance performance in the 0^A-Com^B ($p = 0.481$) condition.

We also conducted pair-wise comparisons (Mann–Whitney tests) of subjects' performance in the B trials of the *Allev-B* versus the Com^A-0^B and 0^A-Com^B conditions. This analysis did not show a significant effect of capturing the dogs' visual attention (eye contact) before hiding the object at the B location in the *Allev-B* compared to the Com^A-0^B condition ($U = 169.5$, $p = 0.569$, Benjamini adjusted $\alpha = 0.05$). However, adding salient ostensive signals (addressing the dog in a high-pitched voice while making eye contact) at location B and avoiding such signals at location A during the B trials (0^A-Com^B) successfully reduced the perseverative search bias. Dogs in the

$O^A\text{-Com}^B$ committed significantly fewer search errors compared to *Allev-B* ($U=79$, $p=0.003$, Benjamini adjusted $\alpha=0.025$).

In sum, we can say that eliminating eye contact next to location B in the $\text{Com}^A\text{-}O^B$ condition did not increase dogs' tendency to perseverate, while addressing the dogs ostensibly at location B in the $O^A\text{-Com}^B$ condition while giving no such cues at location A did decrease their error rate.

General discussion

Although dogs have not been reported to make A-not-B errors during their early development (Gagnon and Doré 1994), in a recent study Topál et al. (2009) found that adult dogs show a strong tendency to perseverate in a two-way search task. It has been argued that dogs' response to human communication is primarily driven by a motivation to satisfy ostensibly cued human imperatives even when it leads to an inefficient or mistaken solution. In an attempt to investigate alternative hypotheses about the underlying mechanism of this error in dogs, in the present study, we replicated some of these results; a comparably great proportion of dogs committed the search error repeatedly in the communicative hiding condition. Among non-human animals so far only dogs have been found to demonstrate such susceptibility to the presence and communicative cues of humans during hiding (see also Kupán et al. 2011), in contrast to human-raised wolves (Topál et al. 2009) and a primate species (common marmosets) (Kis et al. 2012).

However, in the original study (Topál et al. 2009), the non-social and the social conditions differed not only in the behaviour of the experimenter but also in the trajectory of the baited object. In the non-social condition, the ball was moved in a straight line, while the social condition included a 'sham-baiting' that might be attentionally more demanding. To control for this aspect, we combined the social cues with moving the ball in a straight line (*Allev-B*) and found no difference compared to the original social hiding (*Com-H*). The high tendency of the subjects to commit the A-not-B error in the *Allev-B* condition indicates that sham-baiting at location A, a potentially important factor for proactive interference, is of little importance in dogs' search bias towards the empty A location. Similarly, our results show that active search during the A trials is not required to elicit A-not-B errors. Consequently, dogs' errors do not seem to be linked with interference effects in working memory or inhibitory control. An additional aspect to consider could be that the A hiding place comes always first in terms of baiting (whether or not they are allowed to go and search) providing subjects with a salient response hard to inhibit. However, previous results have shown that dogs are able to successfully choose the baited

B location if the ball is hidden according to the same sequence in a non-social way (if the ball is moved with a string) (Topál et al. 2009). Therefore, we have no reason to think that the mere fact that A trials always precede B trials induces the A-not-B error in dogs.

These findings are in line with the view that dogs' perseverative search bias may stem from their propensity to follow human social cues rather than from inhibitory control problems or interference effects in working memory. It is still debated, however, whether dogs follow the enhancing effect of the most recently viewed human cues (as delivered on the B trials) or they recall generalizable information extracted from earlier human behaviour (during the A trials) that dogs may interpret as imperative orders. Therefore, we further investigated the question whether human ostensive cues given either at location A or at location B during the B trials have an influence on the choice behaviour of the dogs if the preceding A hidings remain the same. We tested dogs in a condition where in the B trials, all communicative cues were eliminated at the B hiding place (that is the experimenter did not make eye contact with the subjects as in the original study), and we found that this modification did not influence the dogs' performance. This can be explained by the dogs being sensitive only to some human-given ostensive cues (e.g. high-pitched voice but not eye contact) in situations like the A-not-B task. However, a more parsimonious explanation for our results would be that, due to a floor effect in the *Com-H* and *Allev-B* conditions, subjects could not make significantly more errors even when we removed the eye contact at location B.

More importantly, when in the B trials, the experimenter gave ostensive cues next to location B in contrast to her former imperatives in the A trials to visit location A, dogs showed reduced search bias towards location A compared to the *Allev-B* condition. This indicates that recent ostensive cues delivered in the B trials have a crucial role in directing the search response of the dogs. Nevertheless, dogs did not show a clear preference to location B despite of the recent cuing of the experimenter as well as of the reward being hidden here. The conflicting information of the preceding A trials also seems to have a strong influence on the choices of the dogs (see also Topál et al. 2010 for similar results). Alternatively the fact that during the B trials, the ostensive cues were given next to location B, that is, between the two locations, might direct dogs' attention equally to both hiding places. It is intriguing that in our $O^A\text{-Com}^B$ group, despite watching location B being intensively cued, the dogs chose location B less often than they did in the study by Marshall-Pescini et al. (2010) who provided ostensive cues next to both locations. An explanation might be that in their study, the experimenter's final position at the dog's and owner's B side made dogs show a

higher preference for location B in contrast to our $O^A\text{-Com}^B$ group where the experimenter moved over to the other side of the dog–owner pair closer to location A. However, dogs ($N = 7$) that Marshall-Pescini and colleagues have tested with the latter method in their laboratory also showed reduced preference to the A location compared to our $O^A\text{-Com}^B$ group (Marshall-Pescini et al. personal communication). Therefore, it is possible that other differences in the dog samples contribute to this intriguing discrepancy. We have found, for instance, that differences in the training level and motivation of the subjects can lead to the differences in the dogs' performance in this A-not-B task (Sümegei 2011). In sum, however, we can conclude that in this A-not-B task, human-given ostensive cues can influence the choice behaviour of dogs by the immediate effect of enhancing certain locations or objects as well as by transmitting generalizable information conveyed during the repeated A trials. This latter effect is valid at least as long as the experimenter communicating with the dog in the A trials is present (Topál et al. 2009; Kupán et al. 2011). Recording the looking behaviour of the dogs by eye-tracking techniques (Somppi et al. 2011) can provide more detailed information that can help to answer exactly what part of the ostensive demonstration the dogs pay attention to.

Results from previous research have already suggested that domestic dogs readily adopt inefficient responses in object choice tasks as a result of repeated observations of human action demonstrations (Kupán et al. 2011), and their sensitivity to human social cues may lead to apparently faulty behaviours (Erdőhegyi et al. 2007; Kaminski 2009). Such a disposition, which may result from the domestication of dogs and/or from their extensive experience with humans, is likely to prepare dogs to efficiently learn from humans in a wide range of situations. These claims were further confirmed by the present study showing that dogs' erroneous responses in the A-not-B task do not arise from inhibitory control problems or interference effects in working memory but can be altered by changing the location of ostensive cueing.

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