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Dogs' coping styles and dog-handler relationships influence avalanche search team performance

Silvana Diverio[a,*], Laura Menchetti[a], Giacomo Riggio[b], Costanza Azzari[c], Martina Iaboni[a], Renato Zasso[d], Walter Di Mari[e], Michele Matteo Santoro[f]

[a] LEBA (Laboratory of Ethology and Animal Welfare), Department of Veterinary Medicine, University of Perugia, Via San Costanzo 4, 00126, Perugia, Italy
[b] Via Enrico Besta 46, 00167 Rome, Ital
[c] Via fratelli Calandra 5, 10123 Turin, Italy
[d] ARPAV (Agenzia Regionale per la Prevenzione e Protezione Ambientale del Veneto), Arabba Avalanche Centre, Livinallongo, BL, Italy
[e] GdF (Military Force of Guardia di Finanza), Direzione Veterinaria e Cinofili, Rome, Italy
[f] GdF (Military Force of Guardia di Finanza), Alpine Rescue School, Predazzo, TN, Italy

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ABSTRACT

Avalanche search dogs are valuable resources in the event of environmental disasters. The aim of this study was to determine whether dog search strategies and dynamics of interaction with his handler influence team performance during a simulated avalanche search trial. This consisted in discovering a warm scented article, buried under the snow (−20 cm), within a specific space and time frame (10 min). Twelve dog-handler teams were enrolled in the trial. The dogs' behaviour and dog-handler dynamics of interaction were video recorded and analysed using continuous focal animal sampling. The success of the trial was significantly related to the team ($P < 0.05$). A negative relationship was observed between team performance and the time the dogs spent standing (odds ratio: $OR = 0.66$, $P < 0.05$), gazing at the handler ($OR = 0.85$, $P < 0.05$) or touching him ($OR = 0.55$, $P < 0.05$). Conversely, during successful trials the dogs spent more time exploring sniffing ($OR = 1.80$, $P < 0.001$) and digging intensively ($OR = 3.19$, $P < 0.05$) than during unsuccessful trials. Two principal components (PCs) were extracted. The *"Dog's coping style"* PC described the strategy applied during the search. Traits scoring high in the *"Dog's coping style"* PC indicated exploratory behaviours and a proactive strategy, while reduced locomotor activity and handler-directed behaviours had negative loadings reflecting the passive coping style of the dog. The *"Dog's coping style"* PC predicted the outcome of the trial per se (unadjusted OR: $UOR_{Dog} = 26.51$, $P < 0.05$). The dynamics of interaction established between the dog and the handler during the search was described by the *"Dog-handler relationship"* PC. A high score in the *"Dog-handler relationship"* PC indicated the independent attitude of the dog and the close attention paid to the dog by his handler. The *"Dog-handler relationship"* PC became a predictor of success controlling the *"Dog's coping style"* PC, as shown by the adjusted OR ($AOR_{Dog\text{-}handler} = 3.49$, $P < 0.05$). These findings suggest that a canine proactive strategy and high level of autonomy improve the performance of avalanche dogs. However, a dog's independence does not preclude his ability to perceive the attentional state of the handler that may act as a positive reinforcement.

1. Introduction

Dogs play important roles by assisting humans in various working and social contexts, they herd and guard livestock, protect humans, search for explosives, drugs or people and provide assistance for people with disabilities (Jezierski et al., 2014; Marshall-Pescini et al., 2009; Serpell et al., 2001; Sinn et al., 2010). All of these activities require some innate attitudes, specific training and various social-cognitive skills of the dog (Alexander et al., 2011; Cobb et al., 2015; Miklósi et al., 2004; Sinn et al., 2010; Szetei et al., 2003).

Abbreviations: GdF, Guardia di Finanza; SAGF, Alpine Rescue of Guardia di Finanza; LEBA, Laboratory of Ethology and Animal Welfare; ARPAV, Agenzia Regionale per la Prevenzione e Protezione Ambientale del Veneto; WSA, warm scented article.

* Corresponding author.
E-mail addresses: silvana.diverio@unipg.it (S. Diverio), lallymen@libero.it (L. Menchetti), giacomoriggio@gmail.com (G. Riggio), costanza.azzari@gmail.com (C. Azzari), iabby@hotmail.it (M. Iaboni), rzasso@arpa.veneto.it (R. Zasso), Dimari.Walter@gdf.it (W. Di Mari), Santoro.MicheleMatteo@gdf.it (M.M. Santoro).

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The performance of specialist search dogs does not only depend on their innate olfactory acuity but also on their personality and individual reactions to stimuli (Horváth et al., 2007; Rooney et al., 2007; Sinn et al., 2010; Svartberg, 2002; Szetei et al., 2003). Svartberg (2002) identified a "Shyness-boldness axis" in working dogs and found that active confident dogs, i.e. that scored high in this axis, were more successful in working trials. Horváth et al. (2007) described the behaviour of police dogs in relation to their coping styles, although they did not evaluate the influence of these strategies on practical work situations. Coping styles can be defined as the behavioural and physiological efforts to master the situation distinguishing a proactive or passive strategy (Wechesler, 1995). Proactive coping is nearly always problem-focused with both active avoidance and exploratory behaviours, while passive coping is typically characterized by immobility (Carver and Connor-Smith, 2010 Wechesler, 1995).

Some authors have investigated the effects of training methods on the performance of working dogs (Alexander et al., 2011; Haverbeke et al., 2008; Rooney and Cowan, 2011) while others have emphasized the role of the dog-handler relationship (Arnott et al., 2014; Horváth et al., 2008; Lefebvre et al., 2007; Topál et al., 1997). Lefebvre et al. (2007) observed that working dogs that live at their handler's home and practise sports with them were more sociable, obedient and efficient. Human-canine bonds could positively influence the dog's attention to his handler and improve communication and therefore enhance the performance of working dogs. Dogs are capable of interpreting our communicative cues, such as vocal commands, point gestures, gaze or body direction, tone of voice (Lakatos et al., 2012; Miklósi et al., 2003; Scheider et al., 2011; Topál et al., 2009), or asking for our attention or help (Kuhne et al., 2012; Lakatos et al., 2012; Marshall-Pescini et al., 2013; Miklósi et al., 2003; Virányi et al., 2004). However, dogs not only recognize and respond differently to familiar or unfamiliar people (D'Aniello et al., 2015; Diverio and Tami, 2014; Kuhne et al., 2012; Tami et al., 2008), but attend more to a person who has a close relationship with them (Horn et al., 2013b). Importantly for search dogs, Szetei et al. (2003) found that in the case of contradictory cues, dogs prefer to rely on human communicative signaling (pointing) rather than on olfactory information to localize an hidden object.

Avalanche dogs require high levels of performance in order to protect or save human lives. Therefore, much attention has recently been paid to the science of working dogs by both researchers and rescue professionals. Notwithstanding their social importance, few authors have studied search dogs in an applied environment, especially in the context of avalanche rescue (Alexander et al., 2011; Haverbeke et al., 2008; Lefebvre et al., 2007). Our previous studies evaluated the physiological and molecular aspects of a group of avalanche search dogs (Diverio et al., 2015), as well as the dogs' behaviour during a simulated avalanche search and rescue mission (Diverio et al., 2016). However, to the best of our knowledge, no studies have yet been carried out on the dynamics of dog-handler interactions during an avalanche search. In an avalanche emergency scenario, every dog-handler unit operates as an inseparable team working in extreme environmental conditions, both logistically and climatically, with limited intervention time frames. Indeed, the probability of survival of avalanche victims decreases dramatically after 18 min of burial (Brugger et al., 2001). Empirical evidence suggested that the performance of the team in avalanche interventions is not only affected by the specific features of the dog, such as physiological and behavioural traits, but also by team-related factors, such as communication, cooperation and the dog-handler relationship (Cobb et al., 2015; Diverio et al., 2016, 2015). A scientific approach for evaluating the factors that affect avalanche search activities may provide insights for dog trainers towards optimizing team performance.

The aim of this study was to assess the impact of dog strategy and human-dog interactions on the performance of an avalanche search. The experiment was carried out under highly standardized conditions, set up to avoid human scent pollution and the interference of collateral environmental factors.

2. Methods

All of the experimental procedures in this study were in compliance with the Ethical Committee of Perugia University and with the regulations laid down by the Italian Ministry of Health. There is a standing agreement between the Italian Military Force of Guardia di Finanza (GdF) and the Department of Veterinary Medicine of Perugia concerning the ethical testing of GdF working dogs. This study is part of a broader collaborative project carried out by the Italian Military Force of GdF, the Department of Veterinary Medicine of Perugia University and the Agenzia Regionale per la Prevenzione e Protezione Ambientale del Veneto (ARPAV). The project is aimed at identifying factors influencing the success of avalanche search and rescue missions in order to increase the recovery rate of buried victims.

2.1. Experimental conditions

The study was carried out on the 9th-10th of February 2012 (Day 1 and Day 2) at an altitude of 2170 m at the snow-capped area of Baita Segatini, located just above the GdF Alpine School (SAGF) of Passo Rolle (Trento, Italy; Fig. S1, Supplementary material). Four identical adjacent search fields (10 m × 15 m), named fields A, B, C and D, were arranged to resemble an avalanche fall environment by compressing the snow with a snow-cat (Fig. S2, Supplementary material). Ten minutes before the beginning of the trial, in rotation on each field, an operator drilled a hole (approximately 60 cm deep and 10 cm wide) into the snow. The operator then buried a warm scented article (WSA) inside the hole and covered it with a 20 cm snow layer of snow. The entire procedure was carried out with great care in order to avoid contaminating the area with human scent. The snow in the field area was then compressed with a snow-cat in order to delete signs that could be a visual cue for the handler or the dog for finding the hidden object. The WSA consisted in a plastic bottle (500 ml) filled with hot water (approximately 37 °C) wrapped in a piece of blanket (20 cm × 20 cm) saturated with human scent. This was obtained by leaving the pieces of blankets in close contact with worn clothes in a closed container for 12 h.

During each trial, the staff from the ARPAV continuously monitored the meteorological conditions by collecting data from a small Oregon Scientific portable station (Oregon Scientific Wireless Weather Station, Tualatin, OR, USA) installed at a nearby campsite. During the experimental period, air temperatures ranged from −8.5 to −10.4 °C, with 28% humidity. The wind reached speeds of up to 25 km/h causing a relative wind-chill of −29 °C.

2.2. Subjects

Twelve Avalanche Search and Rescue Military GdF dogs (SAGF dogs) participated in the trial: eleven males and one female, aged from 3 to 8 years, and belonging to various breeds (three Belgian Shepherd Malinois, seven German Shepherd, two Border Collies; Table 1). All SAGF dogs were physically (i.e. found to be in good health by a veterinarian and X-ray negative for hip dysplasia) and behaviourally tested (i.e. absence of behavioural pathologies assessed by a veterinary behaviour consultant) in order to certify their suitability for search and rescue work. The SAGF dogs lived with their handlers all year round and came from different areas of Italy. All of the dogs arrived at Passo Rolle a week before the beginning of the study, in order to allow them to adapt to the new

Table 1
Demographic data of the 12 Avalanche Search and Rescue Military dogs (SAGF dogs).

ID	Breed	Age (years)	Gender
1	Belgian Malinois	9	♂
2	Belgian Malinois	3	♂
3	Belgian Malinois	7	♂
4	German Shepard	6	♀
5	German Shepard	8	♂
6	German Shepard	5	♂
7	German Shepard	6	♂
8	German Shepard	6	♂
9	German Shepard	4	♂
10	German Shepard	8	♂
11	Border Collies	3	♂
12	Border Collies	3	♂

environment. The SAGF dogs were individually kennelled in indoor pens (2.9 m × 2.1 m × 2.3 m) at a station beside the SAGF School of Passo Rolle. Throughout the experimental period, they were fed with commercial, dry dog food. All SAGF dogs had been operational in a search and rescue team at least for 1 year, and their handlers had at least two years of working experience. All SAGF dog-handler teams were highly experienced and certified to carry out search and rescue missions.

2.3. Experimental design

The SAGF dogs participated individually in replicated standardized search trials (one on Day 1 and one on Day 2). The search trial consisted in finding the buried WSA in an assigned field, within a maximum time of 10 min. The rotation of the dogs around the four fields was carried out so that a dog did not work on the same field twice or in the same order (i.e, if a SAGF dog worked as the first team on field A, in the replicate trial he could only work as the second or third team in field B, C or D). In order to avoid intentional or unconscious bias, for each trial neither the handler nor his dog knew where the WSA had been buried. Only the dog was allowed to enter the field area during the search, while his handler could only walk along the perimeter line, vocally encourage his dog and give him instructions by moving alongside to him at a variable distance. If the handler raised his hand to communicate his dog had actively signalled that he had found the WSA, by digging into the snow and barking, the search trial was concluded. The dog was allowed to dig up the WSA, and his handler then rewarded him by playing with him for 3 min. When the SAGF dog found the WSA within the established search time frame, the trial was labelled as "*Success*", or otherwise as "*Failure*". In order to avoid giving false olfactory cues to the dog searching in the same field in the following trial, if the SAGF found the WSA, the empty hole was covered with snow and marked with a flag, a well-known visual signal meaning "*Not of interest*" for the SAGF dogs.

2.4. Behavioural observations

An operator located on a nearby slope with a good overall view filmed the SAGF dogs during the search trials using a Digital Video Camera Recorder (Canon® MD160 and SONY® DCR-SR58, Sony®). For the behavioural analysis, a range of predefined behavioural categories was used (Diverio et al., 2016), modified for this search trial (Table 2). The behavioural categories were analysed in terms of duration or frequency of occurrence, in relation to the dogs' behavioural search pattern (Table 2). A number of behaviours (panting, barking, paw-lifting, snout and lip-licking, circling, body shaking, yawning) were defined as signs of stress, as previously described (Diverio et al., 2016).

We collected data on the dog-handlers' reciprocal position (*Relative spatial position* class; Table 2), by dividing each field into five

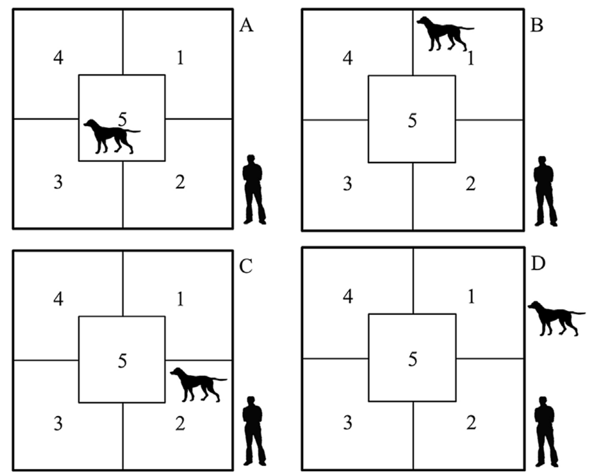

Fig. 1. Virtual division of the field into five virtual areas, with dog and handler positions described in the "Relative spatial position" class. A) Dog in the central quadrant; B) Dog and handler in different quadrants; C) Dog and handler in the same quadrant; D) Dog out of range.

virtual areas (four equal rectangles and a central fifth one; Fig. 1). We also recorded the reciprocal orientation of the dog toward the handler and viceversa (*Relative orientation* class; Table 2). In addition, when the dog was placed laterally to the handler, the right or left side was specified (*Dog's position respect to the handler* class; Table 2). The behavioural variables *Locomotor activities, Dog-handler distance and contacts, Relative spatial position and orientation,* and *Dog's position respect to the handler* were mutually exclusive. The videos were analysed for behaviour duration by continuous focal animal sampling. Behaviour frequency was measured as the total number of occurrences within the search trial. Following the event, two operators recorded the behavioural data from all the videos. Inter-observer reliability exceeded 90% for all behavioural categories.

2.5. Statistical analysis

Behaviour variables measured as duration (Table 2) were converted into rates proportional to the effective search time of each trial [(duration of behaviour/duration of trial) × 100], since the duration of the search time was not the same for all the trials. The percent calculations referred to the number of seconds of the search really evaluated, i.e. excluding the time the dog was off screen. We analysed *Changes of direction* and *Dog-handler contacts* (Table 2) as total number and as a mean number per minute.

We analysed the data using the Generalized Estimating Equations procedure (GEE) with an independent correlation structure and robust standard errors. Binomial and logit were the probability distribution and the link function, respectively. The dog and day of trial were included in the model as the subject and within-subject factors, respectively. The outcome variable was *Success/Failure*, where *Failure* was the reference category. The odds ratio (OR), 95% confidence interval (95% CI), and P value of Wald statistic were calculated.

The same variables were analysed using principal component analysis. Two principal components (PCs) were extracted with covariance matrix and varimax rotation. Behavioural traits with loadings ranging between −0.4 and 0.4 were excluded. We calculated corresponding PC scores for each trial using the Regression method and creating two new variables (PC1 and PC2). Finally, these PCs were evaluated by GEE in order to determine whether they could distinguish between success and failure trials. We calculated both unadjusted (UOR) and adjusted (AOR) odds ratio. The

Table 2
Ethogram of behavioural variables describing dog behaviour and dog-handler relationship during the search trial. Variables were measured as duration (*d*) or frequency (*f*), excluding the time the dog was off screen.

	Behavioural class	Measurement method*	Behavioural variable	Description/Notes
Dog's behaviour	*Locomotor activities*	*d*	Standing	The dog is stationary, with the head up or down
			Walking	The dog is walking
			Running	The dog is running
			Standing sniffing	The dog is sniffing while standing
			Exploring sniffing	The dog is sniffing while walking or running
			Other	The dog showed any other behaviour not included in the forementioned locomotor activities
	Occasional behaviours	*d*	Digging	The dog scratches with front paws on the snow
			Intensive digging	Signalling period was excluded
			Gazing at the handler	
			Playing	
			Signs of stress	Miscellaneous stress-related behaviours (panting, barking, paw-lifting, snout and lip-licking, circling, body shaking, yawning
	Change of direction	*f*	Number of changes of direction of the dog	
Dog-handler dynamics of interaction	*Dog-handler distance*	*d*	0 m (Dog-handler contact)	Estimated distance between dog and handler
			0–1 m	
			1–5 m	
			5–15 m	
			> 15 m	
	Dog-handler contacts	*f*	Number of contacts between the dog and the handler	Number of times a dog's body part comes into physical contact with his handler
	Relative spatial position	*d*	Dog out of range	Dog's position within the field in relation to the position of the handler*
			Dog in the central quadrant	
			Dog and handler in the same quadrant	
			Dog and handler in different quadrants	
	Relative orientation	*d*	Dog frontal-handler frontal (F-F)	Reciprocal orientation of the dog and the handler
			Dog frontal-handler lateral (F-L)	
			Dog frontal-handler back (F-B)	
			Dog lateral-handler frontal (L-F)	
			Dog lateral-handler lateral (L-L)	
			Dog lateral-handler back (L-B)	
			Dog back-handler frontal (B-F)	
			Dog back-handler lateral (B-L)	
			Dog back-handler back (B-B)	
	Dog's position in respect to the handler	*d*	Left	Position of the dog in relation to the side of the handler
			Right	

* See text for more details.

influence of the dog's demographic characteristics (breed and age) on PCs was evaluated using the Kruskal-Wallis or Spearman test. Gender differences were not analysed as only one female dog participated in the study.

We analysed distributions within behavioural categorical variables regardless of the outcome using Chi-Square Goodness of Fit Tests. We used binomial tests to determine whether there were significant differences between (1) the number of dogs that passed the test with *Success* and *Failure* outcome; (2) left and right-preference on total frequencies of the dogs' position; and (3) left and right-preference on frequencies of position for each dog (individual position in respect to the handler).

The statistical analyses were performed using SPSS Statistics version 20 (IBM, SPSS Inc., Chicago, IL, USA). Although $P \leq 0.05$ was the accepted level of statistical significance, trends between $P > 0.05$ and $P < 0.10$ are also presented and discussed.

3. Results

3.1. Team's performance

Out of 24 trials, only 20 were included in the analysis because one SAGF dog had to be excluded because of unexpected health problems, and a video for each of the other two teams was excluded due to technical problems. Nine of the 20 trials (45%) were successful with a mean latency of 148 s (range 37–236 s; SD = 102 s). The success of the trial was significantly related to the team ($\chi^2 = 17.980$; $P = 0.015$): 4 SAGF dogs out of the 11 tested (36%) were successful in both of the two trials (*Success* = 100%), 1 SAGF dog (9%) was successful in one trial (*Success* = 50%), 4 SAGF dogs out of 11 (36%) failed in both trials (*Success* = 0%). The two teams evaluated for only one video were both unsuccessful.

The day of trial did not affect team performance ($\chi^2 = 0.202$; $P = 0.653$): on Day 1 *Success* was achieved in 4 trials out of 10 (40%), on Day 2 in 5 trials out of 10 (50%). No significant differences in trial success were observed in regard to dog age (Wald Chi-Square = 0.011, P = 0.915).

3.2. Team's performance and dog's behaviour

Regardless of the outcome, the SAGF dogs spent most of the time exploring sniffing (36.6%; $\chi^2 = 3029.1$, $P < 0.001$), followed by running (26.7%), standing sniffing (18.1%), standing without sniffing (9.9%), and walking (9.0%). *Occasional behaviours* regardless of the success were: gazing at the handler (13.4%), digging (3.1%), signs of stress (0.5%), intensive digging (0.3%), and playing (0.1%).

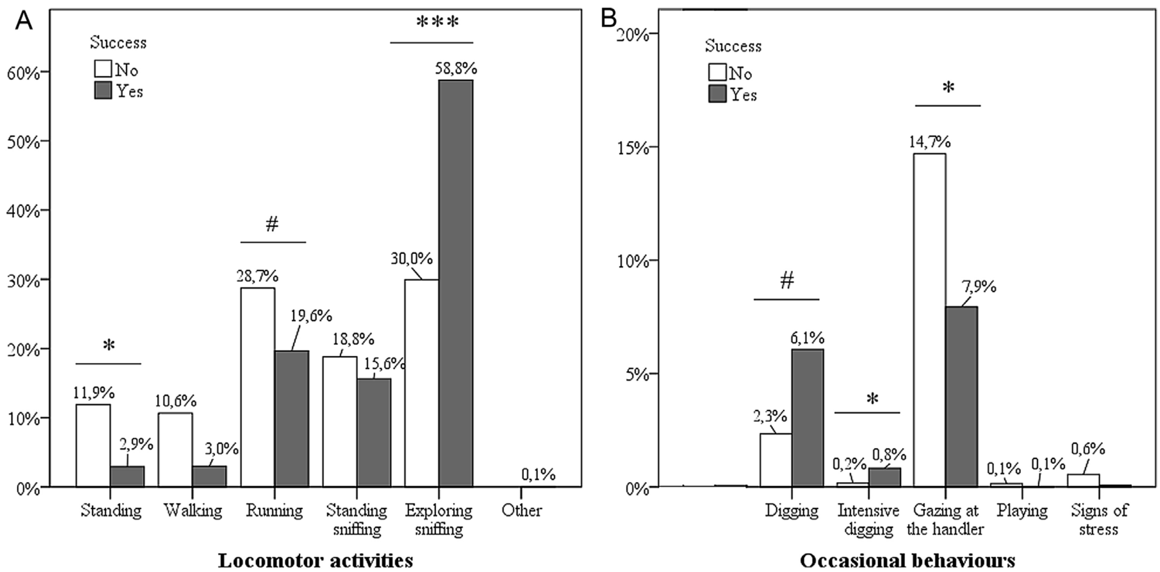

Fig. 2. Rate of behaviours included in "*Locomotor activities*" (Panel A) and in "*Occasional behaviours*" (Panel B) classes according to search trial outcome. *$P \leq 0.05$, ***$P < 0.001$, #$P < 0.10$ successful *versus* unsuccessful trials.

During the successful trials, the dogs spent more time exploring sniffing compared to unsuccessful trials (OR = 1.795, 95% CI = 1.407–2.291, P < 0.001; Fig. 2A). Conversely, unsuccessful trials were associated with more time spent standing without sniffing (OR = 0.663, 95% CI = 0.451–0.974, P < 0.05), with a similar trend for running (OR = 0.937, 95% CI = 0.871–1.008, P < 0.1; Fig. 2A).

The dogs spent more time gazing at their handlers during unsuccessful trials compared with successful trials (OR = 0.853, 95% CI = 0.727–1.001, P < 0.05; Fig. 2B). In the successful trials intensive digging was performed more than during the unsuccessful trials (OR = 3.189, 95% CI = 1.157–8.789, P < 0.05); a similar trend was found for digging (OR = 1.602, 95% CI = 0.925–2.773, P < 0.1; Fig. 2B).

The mean number of the dogs' changes of direction did not significantly differ between *Success* (mean ± SD = 11.4 ± 3.9 changes/minutes) and *Failure* outcomes (mean ± SD = 7.8 ± 1.5 changes/minutes; OR = 1.680, 95% CI = 0.829–3.403, P = 0.150).

3.3. Team performance and dog-handler dynamics of interaction

3.3.1. Distance and contact between dog and handler

Regardless of the trial outcome, the SAGF dogs spent most of the time searching at a distance of 1–5 m (43.1%) and 5–15 m (39.6%) from their handler ($\chi^2 = 4192.3$, P < 0.001). The time spent in contact with the handler (0 m) was 4.0%, between 0 and 1 m it was 6.7%, and greater than 10 m it was 6.5%.

When the SAGF dogs were unsuccessful they spent longer in contact with the handler (Dog-handler distance = 0 m) compared to when they succeeded (OR = 0.551, 95% CI = 0.304–0.997, P = 0.049; Fig. 3A). Similarly, *Failure* outcomes tended to be characterized by a greater number of contacts (mean ± SD = 4 ± 2 contacts) compared with *Success* outcomes (mean ± SD = 1 ± 2 contacts; OR = 0.473, 95% CI = 0.210-1.064, P = 0.070). However, when a number of contacts were calculated per minutes, the differences were not significant (0.27 ± 0.42 contacts/minutes *vs* 0.47 ± 0.35 contacts/minutes in *Success* and *Failure* outcomes, respectively; OR = 0.210, 95% CI = 0.009–4.649, P = 0.323).

3.3.2. Mutual relative spatial position of the dog and handler

Relative spatial position affected performance (Fig. 3B): the SAGF dogs tended to go out of range during unsuccessful trials (OR = 0.925, 95% CI = 0.849–1.008, P = 0.076), while during successful trials they spent more time in the central area of the field (OR = 1.133, 95% CI = 1.023–1.254, P = 0.016) or tended to stay in a different quadrant to their handlers (OR = 1.139, 95% CI = 0.991–1.308, P = 0.067).

3.3.3. Reciprocal relative orientation of the dog and the handler

In successful performances, the dog frontal-handler back orientation tended to be lower (F-B: 0.5% and 1.9% in *Success* and *Failure* outcomes, respectively; OR = 0.184, 95% CI = 0.028–1.206, P = 0.078). The dog-handler relative orientation on successful trials was, in decreasing order: lateral-frontal (L-F: 29.6%), back-frontal (B-F: 20.3%), frontal–frontal (F-F: 19.5%), lateral–lateral (L-L: 16.3%), frontal-lateral (F-L: 6.7%), back-lateral (B-L: 4.4%), frontal-back (F-B: 0.5%), and back–back (B-B: 0.4%).

3.3.4. The dog's position in respect to his handler (Left versus right)

Overall, no significant differences were observed when analysing the dogs' positions during the search trials concerning the distribution between the left (52%) and right (48%) side of the handler (P = 0.064). A significant individual preference was observed on only 3 dogs out of 10: two dogs preferred the left side (P < 0.05) while one preferred the right side (P < 0.01). *The dog's position in respect to his handler* did not affect the outcome of the search trial (Wald Chi-Square = 1.62, P = 0.203).

3.4. Principal component analysis

We initially included the 31 behavioural traits of the behavioural classes in the principal component analysis: *Locomotor activities, Occasional behaviours, Change of direction, Dog-handler distance*, and *Relative spatial position and Relative orientation* (Table 2). Following exclusion according to the loading criterion, 23 behavioural traits were included in the two extracted PCs (Table 3 and Fig. 4). PC1 was most influenced by traits related to the mutual relationship between dog and handler, such as distance and relative orientation. Positive loadings were observed for the frontal position of the handler (*Relative orientation*: F–F and B–F), positioning of dog and handler in different quadrants, frequent changes of direction, and dog-handler distance > 5 m. Negative PC1 loadings were observed for back and lateral orientation of handler (Relative orientation: L-L, B-B, B-L, and F-B) and a distance of 1–5 m between dog and handler (Table 3 and Fig. 4). We named PC1 as "*Dog-handler relationship*".

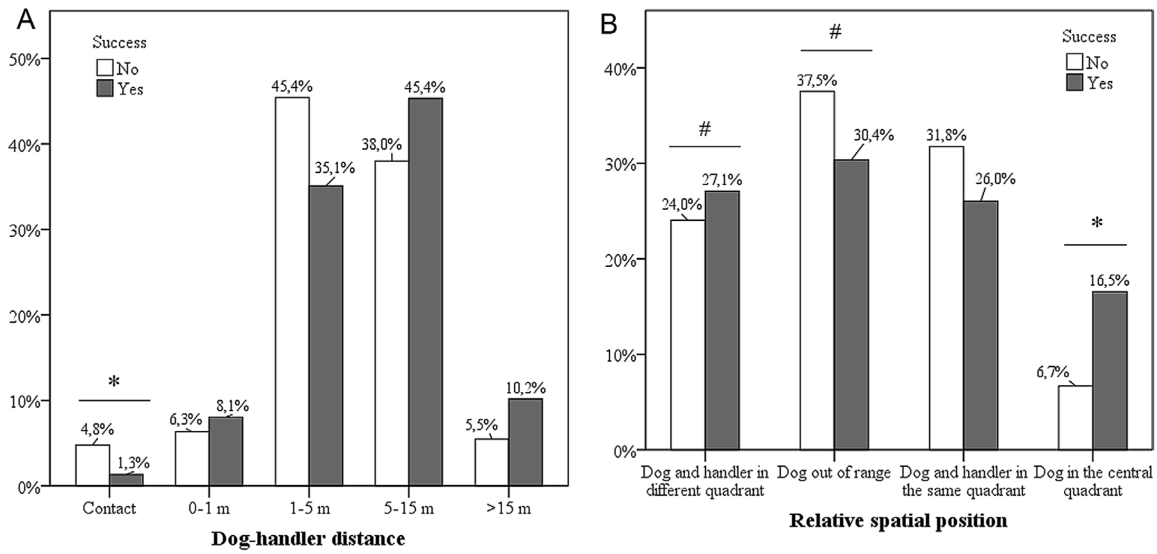

Fig. 3. Rate of behaviours included in "*Dog-handler distance*" (Panel A) and "*Relative spatial position*" (Panel B) classes according to search trial outcome. *P ≤ 0.05, #P < 0.10 successful *versus* unsuccessful trials.

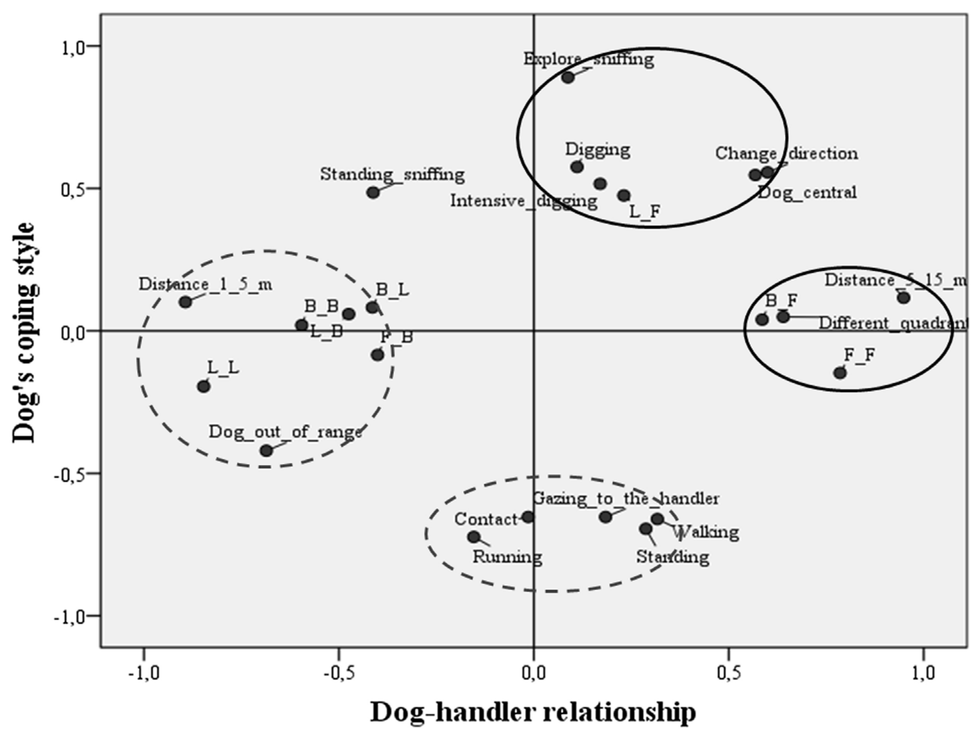

Fig. 4. Factor maps of the principal component analysis. Distributions of behavioural traits in relation to the principal component 1 (*Dog-handler relationship*) and 2 (*Dog's coping style*) extracted in rotated space. Loadings of each variable on the principal component serve as coordinates on the *X*-axis and *Y*-axis, respectively. The black circles (continuous line) show behavioural traits with positive loadings in PCs that are associated with the success of the search trial. The grey circles (dotted line) show behavioural traits with negative loadings in PCs that are associated with the failure of the search trial.

PC2 was mainly influenced by dog behaviour: positive loadings were observed for active exploratory behaviour, such as exploring sniffing, digging, change of direction and searching in the central area of the field, while contact and gazing at the handler, walking, and standing without sniffing had negative loadings (Table 3 and Fig. 4). Therefore, we defined PC2 as *"Dog's coping style"*. Three items (change of direction, dog in the central area of the field, and dog out of range) had high loadings for both *"Dog-handler relationship"* and *"Dog's coping style"* PCs (Table 3 and Fig. 4), suggesting there was not a strong separation between the two components. The two PCs explained 42.7% and 24.0%, respectively, of the variation in the data (Cumulative variance = 66.7%).

3.5. Team performance and principal components

Dog behaviour as described in the *"Dog's coping style"* PC was the factor influencing team performance per se (Table 4). Indeed, the unadjusted OR was significant (UOR_{Dog} = 26.51, 95% CI = 2.07-339.66; P = 0.012) and remained stable even after adjustment (AOR_{Dog} = 29.87, 95% CI = 1.44-618.04; P = 0.028). The odds ratio of traits characterizing the "Dog *-handler relationship*" PC,

Table 3
Loadings of behavioural traits and descriptive statistics of factors extracted with the principal component analysis.[a]

Item	Component	
	1 Dog-handler relationship	2 Dog's coping style
Distance: 5–15 m	**0.949**	
Distance: 1–5 m	−0.894	
Relative orientation: L-L	−0.847	
Relative orientation: F-F	**0.786**	
Dog out of range	−0.686	−0.420
Different quadrant	**0.640**	
Change of direction	**0.599**	**0.556**
Relative orientation: B-B	−0.595	
Relative orientation: B-F	**0.586**	
Dog in the central quadrant	**0.568**	**0.547**
Relative orientation: L-B	−0.475	
Relative orientation: B-L	−0.414	
Relative orientation: F-B	−0.401	
Exploring sniffing		**0.890**
Running		−0.723
Standing		−0.694
Walking		−0.661
Distance: 0 m (contact)		−0.653
Gazing at the handler		−0.653
Digging		0.575
Intensive digging		0.516
Standing sniffing	−0.412	**0.486**
Relative orientation: L-F		**0.475**
% variance explained	42.7%	24.0%
Cumulative % variance explained	66.7%	
Median score	0.18	0.14
Percentile 25	−0.71	−0.57
Percentile 75	0.80	0.59

[a] Only loadings of ≥0.40 or ≤−0.40 are showed. Positive loadings are bolded.

was not significant when the confounding effect of the *"Dog's coping style"* PC was not considered ($UOR_{Dog\text{-}handler}$ = 2.13, 95% CI = 0.78-5.77; P = 0.139). However, when the *"Dog's coping style"* PC was included in the model, the effect of dog-handler relationship became stronger and significant ($AOR_{Dog\text{-}handler}$ = 3.49; P = 0.021; Table 4). We then considered the *"Dog's coping style"* PC as a confounder and the "*Dog-handler relationship"* PC as a predictor of trial success holding the *"Dog's coping style"* PC at a fixed value.

The "Dog-handler relationship" PC was affected by breed (χ^2 = 5.751, df = 2, P = 0.056), with highest score observed for Border Collies (median = 0.96), followed by German Shepherd (median = −0.09), and Belgian Shepherd (median = −0.50). The PCs were not affected by dog age.

4. Discussion

To the best of our knowledge, no studies have yet been carried out that evaluate the dog-handler communicative sphere during avalanche searches. In particular, we investigated the behavioural factors that characterize a successful performance and the dynamics of interaction that develop between the dog and his handler during a search mission. To this aim, we highly standardized the experimental conditions by developing an applied research model for avalanche searches. This experimental model continuously monitored the environmental factors, avoided human scent contamination of the trial area and used a WSA instead of a "disperse victim".

The initial finding of our study was that the success of the trials was significantly related to the team. This was not obvious because all teams had proven experience and had been trained at the same military school. However, the teams undertook an unusual new trial without prior training, i.e. the search of a buried WSA in a confined space not accessible to the handler. This scenario had not previously been used to train this group of SAGF dogs. The limitations imposed by the experimental protocol may explain the high percentage (55%) of *Failure* outcomes. Conversely, we made three assumptions regarding the achievements of the successful teams: dog innate attitude, better overall training, and stronger dog-handler relationships. In actual fact our findings showed that a combination of these factors is required in order to ensure a good performance.

The evaluation of the dogs' behaviour carried out with the univariate analysis showed that the dogs spent more time standing without sniffing, touching and gazing at the handler in failure trials than in successful trials. It is possible that when the trials were unsuccessful, the dogs might have deemed the task impossible and requested the help of their handler rather than make further attempts to find the WSA.

Overall, gazing at the handler is a communicative system that improves problem-solving performance (Miklósi et al., 2003). Dogs develop this eye-gazing behaviour during the domestication process, indicating not only adaptation to the human niche and "enculturation" of the dog, but also a convergent social evolution between these two species on behavioural traits (Miklósi et al., 2004, 2003; Topál et al., 2009). However, in the context of our simulated avalanche, this attitude might be caused by hesitation or lack of self-confidence, thus reducing the likelihood of success. Similarly, physical contact and proximity show the attachment bond linking the working dog to his handler and confirm the role of the "*secure base effect*" played by the handler (Horn et al., 2013a). However, proximity maintenance during the avalanche search did not provide the basis for exploring the environment but seemed to indicate a request for assurance in times of uncertainty and emotional distress. Hesitation behaviour is undesirable during an avalanche search due to the limited intervention time frame (Brugger et al., 2001). Merola et al. (2014) considered dogs' eye-gazing behaviour as a process of "social referencing": a dog looks towards his owner when confronted with a new and potentially scary object or event, to request emotional cues that can help him face the problem. Marshall-Pescini et al. (2013, 2008) found that gaze alternation behaviour between the apparatus and care-

Table 4
Score (mean ± standard deviation, SD), unadjusted and adjusted odds ratio, with 95% confidence interval (95% CI), to performance success of the variables extracted with the principal component analysis.

Variable	Mean ± SD		Unadjusted[1]		Adjusted[2]	
	Success	Failure	Odds ratio (95% CI)	P value	Odds ratio (95% CI)	P value
PC1: Dog-handler relationship[3]	0.35 ± 0.77	−0.29 ± 1.10	2.13 (0.78–5.77)	0.139	3.49 (1.21–10.11)	0.021
PC2: Dog's coping style[4]	0.75 ± 0.63	−0.61 ± 0.82	26.51 (2.07–339.66)	0.012	29.87 (1.44–618.04)	0.028

[1] Model: (Intercept), PC1 or PC2; Dependent Variable: Success.
[2] Model: (Intercept), PC1, and PC2; Dependent Variable: Success.
[3] Component describing dog-handler relationship during the search trial. High scores included dog's independent behaviour and high handler attention towards his dog.
[4] Component describing the strategy dogs used during the search trial. High scores included proactive copying style while low scores included passive copying style.

giver increased when the task became unsolvable. Dogs performing better during problem solving tasks seemed to be less dependent on their owners because they spent their time interacting with the apparatus rather than looking up at humans for help. Udell (2015) found that dogs spent much more time gazing at humans than wolves, which demonstrate greater persistence on the task and have higher success rates. These findings suggest that gazing at humans may interfere with the independent problem-solving behaviour of dogs. Interestingly, trained dogs tended to look less at their owner during the problem solving task (Marshall-Pescini et al., 2008) and were less willing to follow misleading suggestions (Prato-Previde et al., 2007) compared with untrained dogs. However, specific training regimes, such as agility training, can increase dependence toward humans (Marshall-Pescini et al., 2009).

Several research groups studying social referencing paradigms (Flom and Gartman, 2015; Merola et al., 2014; Udell, 2015) recently confirmed that the emotional messages conveyed by humans can affect the exploratory behaviour of dogs. When the dogs received a positive emotional message, their exploratory activity increased and they spent more time searching for the new object. Conversely, if the dogs received a negative or fearful message they preferred to stay close to their owner, thus reducing their interaction with the object (Merola et al., 2014). In Udell's study (2015), the dogs that were encouraged by familiar humans persisted significantly longer on the task. In our study, we could not investigate the dogs' reactions to various types of human emotional messages because the vocal and facial emotional expressions of the handler were neither standardized nor evaluated, which may be the subject of further research. However, our findings seem to confirm that human-directed behaviour, including gazing and contact during search, were communicative tools that might convey uncertainty, difficulty and the perception of the problem encountered as being unsolvable. According to recent studies (Flom and Gartman, 2015; Merola et al., 2014) and empirical knowledge in the field of avalanche search, we can assume that a positive and reassuring message (verbal, nonverbal, and paraverbal) from the handler could encourage avalanche dogs to interact with the environment and increase their determination to accomplish the task.

In our study, we found that only 3 dogs out of 10 preferred to search maintaining a right or left position respect to his handler, which was probably due to the handler's training habits. No attempt was made to determine whether there was a lateralized process during sniffing, because of the technical limitations of the video data collection imposed by working in experimental search fields resembling an avalanche fall environment at high altitude. In addition, we considered that the SAGF dogs were highly trained search animals as they belong to a militarized police force and their training could involve working on the preferred side of the handler. Dogs lateralization has been demonstrated by various types of behaviour, including paw usage and their response to visual and acoustic stimuli (Marshall-Pescini et al., 2013; Siniscalchi et al., 2013a, 2008). Siniscalchi et al. (2011) found that dogs show striking asymmetries of nostril use when sniffing. When subjected to nonaversive stimuli, dogs initially preferred to investigate with their right nostril, which they generally use first in response to arousal stimuli, and then shifted towards their left. This suggested a lateralization between the hemispheres involved in the scent analysis. This asymmetry may also involve structures of the olfactory epithelium, such as receptor expression, as reported for other animals (Frasnelli et al., 2010). Further research should be carried out on this topic, as well as on the influence of training methods on performance. In fact, previous studies have shown that handlers can achieve the best results by using positive stimuli and short reinforcement times (Alexander et al., 2011; Browne et al., 2013; Haverbeke et al., 2008). Affenzeller et al. (2016) have recently demonstrated that engaging in playful activity post-learning tasks improved training performance in dogs, thus suggesting that a positive emotional state may play a key role in achieving trial success.

In our study, the principal component analysis was carried out in order to further investigate the dogs' behavioural traits. The component called *"Dog's coping style"* focused mainly on the behavioural traits which describe his concentration on work and outlined the strategy applied to cope with this unusual search task. Traits scoring high in the *"Dog's coping style"* component indicated exploratory behaviours and a problem-focused strategy, such as exploring sniffing, digging, and changes of direction. This proactive dimension was positively associated with performance success. On the contrary, reduced locomotor activity, such as walking and standing, as well as handler-directed behaviours, including contact and referential gazing, had negative loadings in this component. They may indicate a passive attitude and characterized the *failure* trials.

The *"Dog's coping style"* component which describes the proactive-passive dimension of avalanche dogs could be comparable to the "Shyness-boldness axis" previously used to investigate human and animal personality traits (Scott and Fuller, 1998; Svartberg, 2002), even if personality and coping style are not equivalent concepts (Carver and Connor-Smith, 2010). Svartberg (2002) demonstrated that a high score on the shyness–boldness axis including active, confident, playful, explorer and curious dogs correlated with the success of working trials. Foyer et al. (2016) recently found that military working dogs approved for further training scored higher on emotionality in a standardized temperament test, and had higher levels of cortisol compared with nonapproved dogs. Research has confirmed the existence of correlations between personality and performance in scent detection and police dogs, and the validity of temperament assessment tests for selecting military working dogs (Eriksson, 2009; Gosling et al., 2009; Rooney et al., 2007; Sinn et al., 2010). This is in agreement with our results, since the traits described by the *"Dog's coping style"* component predicted the outcome per se ($UOR_{Dog} = 26.5$), regardless of the relationship the SAGF dog established with his handler. We can state that a dog's proactive search is the winning strategy in avalanche rescues.

In Svartberg's study (2002), there were no correlations between breed or sex and well performing dogs, although some breeds such as German shepherds and male dogs scored higher in the Boldness dimension. Starling et al. (2013) confirmed the existence of the shy–bold continuum in dogs and included German shepherds in the boldest breeds, while Jezierski et al. (2014) claimed this breed to be superior in drug detection performance due to their elevated scenting ability. Polgár et al. (2016) showed that olfactory acuity was highest in dog breeds specifically selected for scent work, which retained the abilities for which they were originally bred. In contrast, Svartberg (2005) found no correlations between the original functional behaviour of breeds and their present-day behavioural characteristics. The differences observed in the olfactory abilities of various dog breeds are probably due to differences in their polymorphism rather than the number of olfactory receptor genes (Lesniak et al., 2008). However, few comparative studies have been carried out and the existing results are contradictory, depending on the experimental protocol and searching environment, genetic lines and the breed of the search dogs (Jezierski et al., 2014; Polgár et al., 2016; Rooney and Bradshaw, 2004). In our study, differences found in the PCs regarding the dog's breed and sex were indecisive due to the low number of replicates. However, an innate or genetic predisposition to proactive strategy manifested by puppies at an early age cannot be ruled out (Svartberg et al., 2005; Gosling et al., 2009). Evaluating the *Dog's coping style* PC may help when selecting avalanche dogs. However, further studies are required in order to assess its reliability and predictive validity.

Although the component describing the dog's behaviour, i.e. "*Dog's coping style*" PC, could predict the success of performance per se, our findings do not diminish the role of the handler during an avalanche search. Previous studies have shown that the quality of the handler's relationship and approach can affect the communicative behaviours, attention and performance of working dogs used both for military and civilian purposes (Alexander et al., 2011; Arnott et al., 2014; Horn et al., 2013b; Horváth et al., 2008; Kuhne et al., 2012; Lefebvre et al., 2007). However, a strong dog-handler relationship is not automatic (Lefebvre et al., 2007) and there are some conflicting data relating to the influence of dog-human relationship on problem solving. Hare et al. (2002) showed that the extent to which a dog is exposed to humans does not affect their ability to solve problems, while Topál et al. (1997) and Udell (2015) suggested that a strong attachment to humans leads to an increase in a dog's dependence toward his owner and a reduction in his problem solving skills.

In our study, the relationship established between the dog and his handler during the search was specifically described by the component named *"Dog-handler relationship"*. High scores in the *"Dog-handler relationship"* PC indicated the independent attitude of the dog that remained in the central quadrant at some distance from his handler, but also the close attention paid by the handler towards his dog, i.e. frontal position of the handler. The *"Dog-handler relationship"* PC became a predictor of a successful search controlling the *"Dog's coping style"* component, as shown by the adjusted odds ratio ($AOR_{Dog\text{-}handler} = 3.5$). Interestingly, some behavioural traits had high loadings on both PCs suggesting that some aspects of dog's coping style also affected the dog-handler relationship or vice versa. Their position in the central quadrant enabled the dogs to monitor the search area and better distribute their exploratory activities, which made it easier for them to find the WSA buried under the snow. Moreover, SAGF dogs spend more time far away from their handlers in successful trials compared with failures, thus confirming the importance of independence and proactive behaviours during a search. However, the handler's attention, which is displayed by his body orientation, should be focused on the activities of his dog. The search can be part of a cooperative game between the dog and his handler. The dog can then interpret the handler's attention as his active participation in this "game", acting as positive reinforcement and motivating his exploratory behaviour. Overall, these findings suggest not only that a mixture of dog autonomy and handler attention improves the performance of avalanche dogs, but also that the independence of the dog does not preclude his ability to perceive the attentional state of his handler.

Several studies confirmed that the dog is able to use more subtle cues in addition to the human pointing gesture, such as head orientations, gaze directions and body positions (Gácsi et al., 2004; Lakatos et al., 2012), take into account contextual information (Marshall-Pescini et al., 2013; Scheider et al., 2011) and determine whether the gesture is intentional or not (Kaminski et al., 2012). Szetei et al. (2003) showed that in conflictual contexts, i.e. when a dog cannot see where food is placed, he prefers to rely on human cues rather than on olfactory information. Interestingly, other authors showed that dogs are able to differentiate the focus of human attention by modifying their behaviour accordingly (Call et al., 2003; Horn et al., 2013b; Marshall-Pescini et al., 2013; Virányi et al., 2004). In agreement with our findings, Gácsi et al. (2004) found increased hesitation and longer response latency when the handler assumed a back-facing orientation during the object-fetching tasks. Physical contacts were not required by the successful avalanche dogs but the attentional state of the handler could provide dogs with a "*secure base effect*" so they feel free to explore the environment. Previous research showed that dog-human attachment affects dogs' exploratory behaviour, as well as the "*secure base effect*" (Siniscalchi et al., 2013b). Our findings suggest that strong attachment bonds between military handlers and their working dogs could contribute to the success of avalanche searches.

5. Conclusions

For the first time we investigated the dog-handler relationships and strategies used by avalanche dogs during a search trial, as well as how these aspects influence the success of their performance. The coping style of avalanche dogs appears to be the main factor associated with performance. A proactive strategy, including intensive exploratory behaviours and few referential gazes toward the handler, increased the likelihood of success. However, if dog's coping styles are levelled, the relationship with the handler becomes the discriminating factor between the success and failure of the search. The autonomy and independence of avalanche dogs improved search performance. However, this search and rescue dog seemed to recognize the attentional state of his handler and may use it as "*secure base effect*" for enhancing his exploratory behaviours.

In the field settings, it is difficult to distinguish the contribution of genetic and behavioural aspects, training methods and dog-handler cooperation on search performance. Further research is required to investigate the reliability of proactive-passive dimensions as well as the effect of avalanche dog personalities and emotional structures on performance. Finally, our experimental model could have practical implications for refining avalanche dog training and optimizing rescue operation strategies thus increasing the success rate of rescue operations for disperse victims.

Conflict if interests

None.

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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.applanim.2017.02.005.

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