



Robot-Locust Social Information Transfer Occurs in Predator Avoidance Contexts

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Accepted: 12 January 2024 / Published online: 22 January 2024
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Abstract

Social learning is an evolutionarily important ability increasingly attributed also to invertebrate species. Interfacing robots with animals represents a promising strategy to investigate social learning. Herein, we studied if the gregarious form of *Locusta migratoria*, a particularly suited model to examine social learning, can use social information provided by robotic demonstrators to optimize their predator avoidance. Robotic demonstrators with different silhouettes and colours (biomimetic or neutral) were used to investigate if their rotation on a rod (e.g. hiding behaviour) elicited the same behaviour in neighbouring locusts. Locusts' responses were affected by different robotic demonstrators, observing a significant impact of the biomimetic silhouette in reducing the latency duration, and in promoting social learning (e.g. locusts displaying hiding behaviour after observing it in robotic demonstrators). A significant impact of colour patterns in triggering socially induced hiding behaviour was also recorded, especially when the biomimetic silhouette was coloured with the gregarious-like pattern. This research indicates gregarious locusts exploit social information in specific ecological contexts, providing basic knowledge on the complex behavioural ecology and social biology in invertebrates. The proposed animal-robot interaction paradigm shows the role of robots as carrier of social information to living organisms, suggesting social biorobotics as advanced and sustainable approach for socio-biology investigation, and environmental management.

Keywords Animal–robot interaction · Biohybrid complex network · Biomimetics · Insect · Social learning · Social robotics

1 Introduction

Social behaviours have evolved independently in many and divergent animal taxa during evolution, exerting a fundamental function in contributing to the survival of individuals [1]. Among social behaviours, social learning (e.g. agents learning through observation of others) represents an evolutionarily important ability as it promotes novel behaviours within and across generations [2–4]. Socially influenced learning allows animals (including humans) to update their information on the environment by observing

other individuals' behavioural displays, and avoiding the costs related to effort and risk of individual learning. However, theoretical models shows that social learning can also be error-prone, inducing individuals to collect inadequate/obsolete information in unstructured scenarios [5–7]. To balance the benefits and risks of social learning, animals have to perform selective processes on how and when to exploit social information [8]. These issues have been studied by multiple disciplines including zoology, psychology, social sciences and humanities, artificial intelligence, robotics [9–15]. Social learning has been widely investigated in vertebrates [16–18], although a growing number of studies reports this high-order learning ability also in invertebrates [19–24], whose relatively simple nervous system make them more suitable to investigate the evolution and mechanisms of this phenomenon. However, many studies focused on the psychological processes underlying the acquisition of social information [25], while the contexts under which social learning occurs remain largely unexplored.

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Recently, robotics has been proven to be a promising strategy to investigate social learning in both vertebrates [26, 27], and invertebrates [24]. The broad field of robotics aims at playing a key role in science by developing innovative robotic platforms and strategies to enable new scientific discoveries [28]. Among the emerging fields of robotics, animal-robot interaction and ethorobotics are offering a new paradigm for the study and control of animal behaviour [29–31]. Here, zoology and ethological principles are exploited in the engineering design process to reproduce physical models eliciting selected behaviours in animals, and ecologically interacting with them [32–35]. This approach at the interface of ethology and engineering has been envisioned to create a positive feedback where animal-robot interaction will increase our understanding of animal cognition, and in turn will advance the design of new artificial agents [29, 36, 37]. Also, robotic interfaces used to study animal social interactions may allow us to dissect visual and tactile cues from other cues [38], avoid feedbacks from non-focal living conspecifics [39], as well as to promote the 3Rs Principle, the gold standard for protecting animals in laboratory conditions [40].

Herein, we proposed to use the animal-robot interaction paradigm to investigate social information transferring in the gregarious form of *Locusta migratoria* (Linnaeus 1758) (Orthoptera: Acrididae). Animal species living in large groups with overlapping generations are particularly suited to examine the evolution and ecology of social learning [21, 41]. Gregarious locusts may be elective models for social learning investigation as they usually feed together and in a synchronized way with conspecifics [42], and show strong learning abilities at individual level [43–45].

We studied if locusts can use social information provided by conspecific-like artificial agents (hereafter biorobotic demonstrators) to optimize their predator avoidance behaviour. In particular, we focused on the hiding behaviour, a positioning predator avoidance response displayed by locusts when located on a branch consisting in hiding from a looming stimulus by moving around the branch [46]. In this study, we investigated if biorobotic demonstrators rotating on a rod can elicit the same behaviour in neighbouring locusts sitting on a different rod. We used biorobotics demonstrators with different colour patterns (e.g. those of gregarious and solitary forms), and silhouettes (e.g. biomimetic, elliptical) to test if and how shape and pigmentation affect this social behaviour. This research would unveil the ability of locusts in exploiting social information from a conspecific to avoid a potential predator although no threatening/looming stimuli were associated.

2 Materials and Methods

2.1 Ethics Statement

The present study complies with the Guidelines for the Use of Animals in Research [47], and with the 7010–2020—IEEE Recommended Practice for Assessing the Impact of Autonomous and Intelligent Systems on Human Well-Being [48]. The legal requirements of Italian legislation (D.M. 116,192), and EU regulation [49] were followed. All experiments were characterized by behavioural observations, and no specific authorizations are needed in the country where the experiments were conducted.

2.2 Animal Rearing and General Observations

Locusts were maintained in controlled conditions at temperature of 25 ± 1 °C, relative humidity (R.H.) of $55 \pm 5\%$, and under a 16 h:8 h light:dark photoperiod. The diet consisted of wheat, vegetables and water that were provided *ad libitum* to locusts. The same laboratory conditions described above were also present during experiments. Light intensity around the test arena was approximately 1000 lx, and the diffused laboratory lighting was used to reduce reflection and phototaxis. An observer focally recorded the behaviour of locusts during the experiments. The arena was enclosed by a surrounding white filter paper wall (Whatman), and the observer's attire was a white coat, all aimed at reducing any potential external influence on the behaviour of *L. migratoria* [45].

2.3 Biorobotic Demonstrators and Experimental Platform

The biorobotic demonstrators reproduced the size and morphology of adult *Locusta migratoria* (Fig. 1a). The biorobotic demonstrators' main body (e.g. head, thorax, and abdomen), two forelegs, two middle legs, two hindlegs, two tegmina, and two antenna were designed using SolidWorks (Dassault Systemes, Vélizy Villacoublay, France) and fast prototyped separately in a bio-compatible resin (VisiJet® M3 Crystal, 3D Systems). Once assembled, the biorobotics demonstrators were painted with non-toxic pigments to visually resemble the integumental colour pattern of *L. migratoria* adults in both their gregarious and solitary forms. One biorobotics demonstrator was coloured white as a control. The biorobotic demonstrators were 57 mm long between the distal end of the head and the tegmina (Fig. 1b).

The same process was used to fabricate and paint non-biomimetic demonstrators (hereafter neutral demonstrators) consisting in a simple elliptical silhouette.

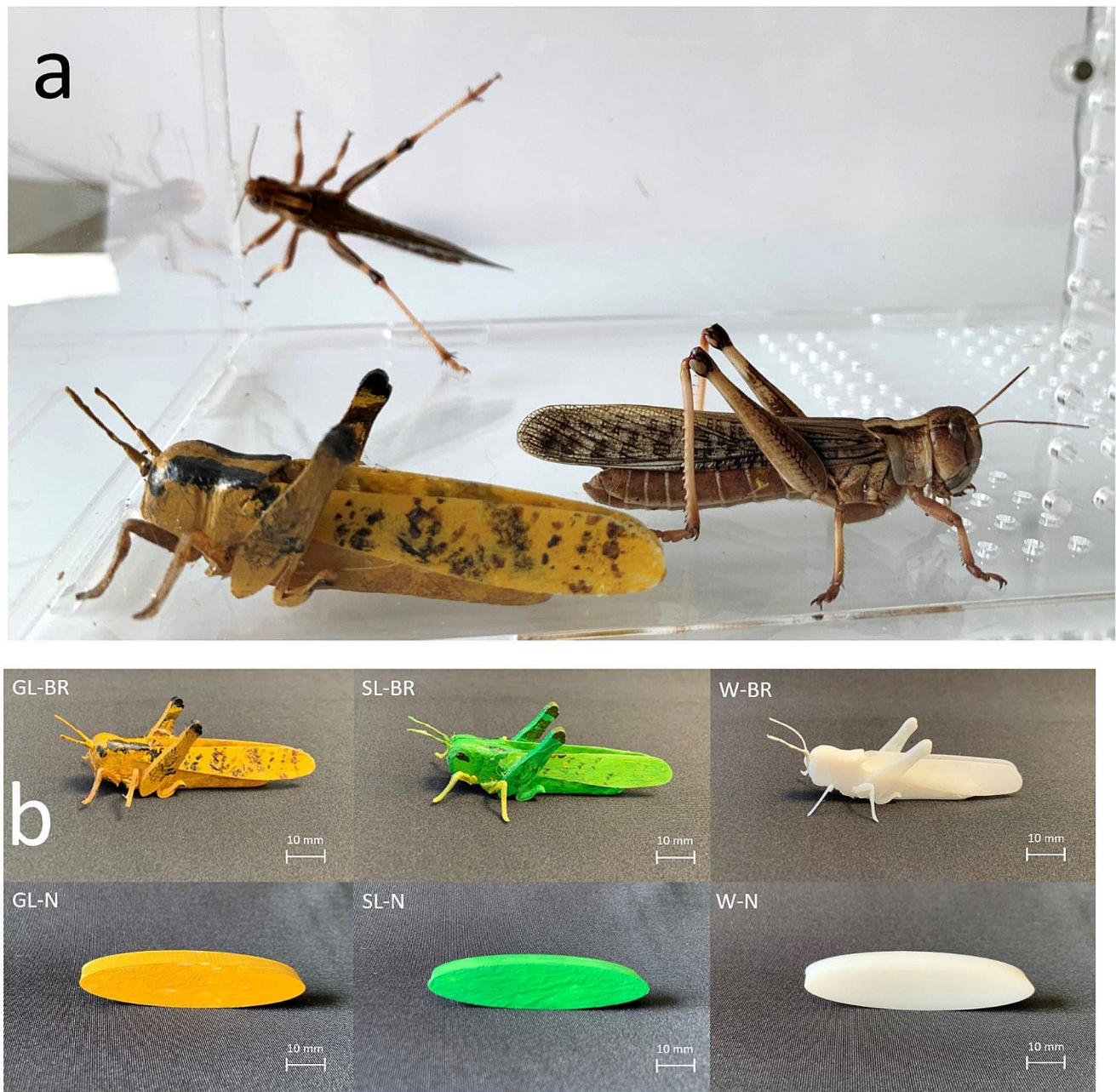


Fig. 1 The biorobotic demonstrator with *Locusta migratoria* individuals **a**. Different robotic stimuli to which *L. migratoria* was exposed are shown in **b**: gregarious-like biorobotic demonstrator (GL-BR), soli-

tary-like biorobotic demonstrator (SL-BR), white biorobotic demonstrator (W-BR), gregarious-like neutral demonstrator (GL-N), solitary-like neutral demonstrator (SL-N), white neutral demonstrator (W-N)

The experimental platform (Fig. 2a) consisted of a carbon fibre rod (\varnothing 10 mm, length 350 mm) horizontally suspended by two ABS (acrylonitrile butadiene styrene) holders at its ends. Both biorobotic and neutral demonstrators were individually located on the horizontal rod by using a small rectangle of double-sided tape. The biomimetic hiding behaviour of artificial demonstrators was displayed by the rotation of the rod activated by a servomotor (H.A.R.D. HS3004) connected to one end of the rod. The activation

and control of this mechatronic platform was carried out by an external microcontroller (Arduino, Mega 2560). A similar but static rod (e.g. not electronically actuated, nor able to rotate by inertia) horizontally suspended by two holders was located parallel, at a distance of 200 mm, to the actuated rod, and was used to position the *L. migratoria* individuals during experiments (Fig. 2b).

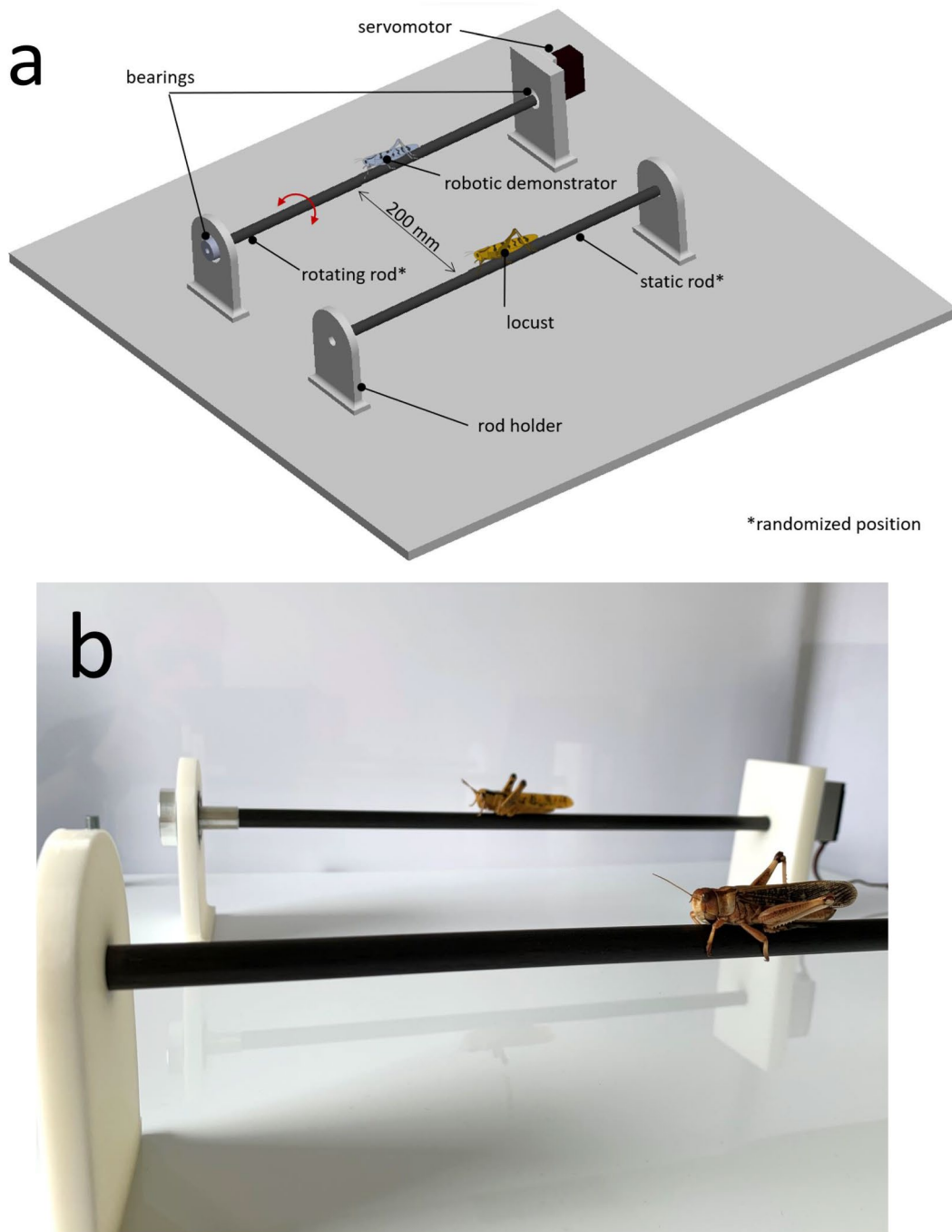


Fig. 2 Schematic illustration of the experimental platform **a**, and a picture of the biorobotic demonstrator and a locust individual positioned on the two rods of the experimental platform **b**

2.4 Effect of Different Robotic Demonstrators in Transferring Social Information in Locusts

Here, we investigated the presence of social learning in *L. migratoria*, and the impact that different colour patterns and shapes of robotic demonstrators have on it. Locusts were individually placed in the centre of the static rod, making sure they assumed a sitting position. After 5 min, an opaque

screen, placed between the static rod and the rotating one, was gently removed allowing the locust to visually perceive a robotic demonstrator located in the centre of the rotating rod (kept motionless). After 10 min of acclimatization, the hiding behaviour of robotic demonstrators was reproduced by rotating 90° the rod. The 10-minute acclimatization period, during which the locusts observed the static robotic demonstrators, is a crucial part of the experiment, as it also

allowed us to discern the effects of visual perception, presence, and behaviour without the effect of movement. After each replicate, the clockwise and counterclockwise rotation of the robotic demonstrators with respect to the static rod was alternated, as well as the position of the two rods was randomly shifted to avoid any directional bias.

Locusts were exposed to different robotic demonstrators including a gregarious-like biorobotic demonstrator (GL-BR), a solitary-like biorobotic demonstrator (SL-BR), a white biorobotic demonstrator (W-BR). Furthermore, locusts were exposed to a gregarious-like neutral demonstrator (GL-N), a solitary-like neutral demonstrator (SL-N), a white neutral demonstrator (W-N), (Fig. 1b).

For each tested locust exposed to robotic demonstrators we recorded: (i) the latency duration, consisting in the time needed to display any avoidance response after the robotic demonstrator started moving (the latency duration recording was terminated after a time window of 30 s, after which the locusts were considered to give no response); (ii) number of individuals performing different behavioural responses (e.g. hiding behaviour, jumping escape, no response); in case of hiding behaviour, (iii) if the locust hiding behaviour occurred in the same direction of that of the robotic demonstrator.

Each individual *L. migratoria* was subjected to a single test. The total number of locusts exposed to the various stimuli, including GL-BR, SL-BR, W-BR, GL-N, SL-N, and W-N, amounted to 57, 62, 53, 60, 68, and 58, respectively. Any locusts that jumped away before the robotic demonstrators initiated movement or those that did not settle on the rod but instead roamed around the arena were excluded from the analysis. As a result, data from 50 locusts were analysed for each robotic demonstrator.

2.5 Data Analysis

Data about the latency duration in locusts exposed to different robotic demonstrators were neither normally distributed (Shapiro–Wilk test, $p < 0.05$), nor homoscedastic (Levene's test, $p < 0.05$). So, we used non-parametric statistics to analyse these data. In particular, the Wilcoxon/Kruskal–Wallis test, followed by Dunn's multiple comparison test with Bonferroni correction, was used to analyse the impact that different pigmentation of the robotic demonstrators had on the duration of the latency. We relied on the Wilcoxon test to analyse the impact that different silhouette of the robotic demonstrators had on the duration of the latency.

The impact of different robotic demonstrators on the number of locusts displaying hiding behaviour, jumping escapes, and no response was analysed by using a generalized linear model with a binomial error structure and one fixed factor (the robotic demonstrator): $y = XB + \epsilon$, where

y is the vector of the observations (i.e. the locust response), X is the incidence matrix, β is the vector of the fixed effect (i.e. the robotic stimulus) and ϵ is the vector of the random residual effects. A threshold value of $p = 0.05$ was used to detect significant differences among values.

To analyse differences in the number of locusts that displayed the hiding behaviour in the same or opposite direction of that of a robotic demonstrator a chi-squared test with Yates's correction ($p = 0.05$) [50] was used. Data from all tests were analysed by R software v4.2.0 (Stats Package).

3 Results

We found that different colour patterns of biorobotic demonstrators had a significant effect on locust latency duration ($\chi^2 = 12.425$, $d.f. = 2$, $P = 0.0020$). Latency duration was importantly shorter in presence of the pigmentation of GL-BR than of SL-BR ($Z = 2.533$, $P = 0.0339$), and W-BR ($Z = 3.410$, $P = 0.0019$) (Fig. 3a). However, for the neutral demonstrators, their different pigmentation (e.g. GL-N, SL-N, W-N) did not significantly affect the latency duration of locusts ($\chi^2 = 1.992$, $d.f. = 2$, $P = 0.3693$) (Fig. 3b).

The latency duration was significantly different when robotic demonstrators with biomimetic and elliptical silhouettes were presented. Latency was significantly shorter with GL-BR than with GL-N ($\chi^2 = 49.93$, $d.f. = 1$, $P < 0.0001$) (Fig. 3c). Latency was significantly shorter with SL-BR than with SL-N ($\chi^2 = 24.228$, $d.f. = 1$, $P < 0.0001$) (Fig. 3d), as well as with W-BR than with W-N ($\chi^2 = 24.36$, $d.f. = 1$, $P < 0.0001$) (Fig. 3e).

Locusts' behavioural responses varied with different biorobotic demonstrators. When exposed to GL-BR, significantly more locusts exhibited hiding behaviour compared to jumping escape ($\chi^2 = 54.437$, $d.f. = 1$, $P < 0.0001$) and unresponsiveness ($\chi^2 = 67.349$, $d.f. = 1$, $P < 0.0001$), (Fig. 4a). Similar results were observed with SL-BR, where more locusts displayed hiding behaviour over jumping escape ($\chi^2 = 54.437$, $d.f. = 1$, $P < 0.0001$), (Fig. 4b). In the case of W-BR, no significant differences were found in the number of locusts displaying various behavioural responses ($\chi^2 = 6.311$, $d.f. = 2$, $P = 0.0429$), (Fig. 4c).

The behavioural responses of locusts were also influenced by different neutral demonstrators. When exposed to GL-N, a significantly higher number of locusts displayed no response compared to those exhibiting hiding behaviour ($\chi^2 = 28.653$, $d.f. = 1$, $P < 0.0001$) and jumping escape ($\chi^2 = 47.43$, $d.f. = 1$, $P < 0.0001$), (Fig. 4d). Similarly, SL-N led to more locusts displaying no response over hiding behaviour ($\chi^2 = 63.925$, $d.f. = 1$, $P < 0.0001$) and jumping escape ($\chi^2 = 47.732$, $d.f. = 1$, $P < 0.0001$), (Fig. 4e). When exposed to W-N, a significantly higher number of

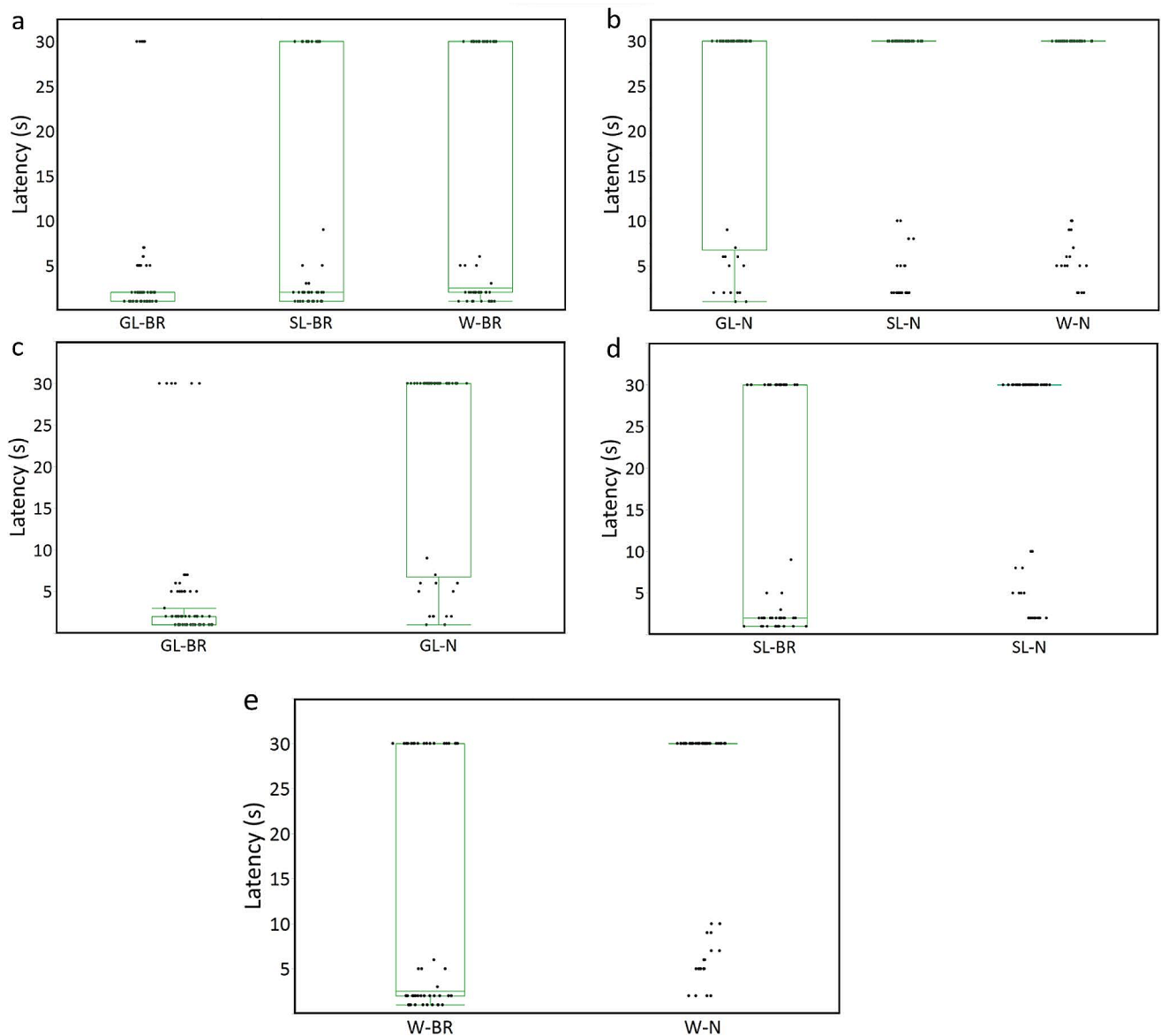


Fig. 3 Differences in latency duration in *Locusta migratoria* post exposure to differently coloured biorobotic demonstrators **a**, differently coloured neutral demonstrator **b**, biorobotic and neutral demonstrators with a gregarious-like colour **c**, biorobotic and neutral demonstrators

with a solitary-like colour **d**, biorobotic and neutral demonstrators with a white colour **e**. For each box plot, it is indicated the median and its range of dispersion with the green line (lower and upper quartiles, as well as outliers). Dots indicate dispersion of data values

locusts displayed no response compared to hiding behaviour ($\chi^2=67.349$, $d.f. = 1$, $P<0.0001$) and jumping escape ($\chi^2=54.437$, $d.f. = 1$, $P<0.0001$), (Fig. 4f).

Each behavioural response was performed by a different number of individuals depending on the robotic demonstrator exposed. Hiding behaviour was more prominent when exposed to GL-BR compared to GL-N ($\chi^2=41.409$, $d.f. = 1$, $P<0.0001$), SL-BR ($\chi^2=11.753$, $d.f. = 1$, $P=0.0006$), SL-N ($\chi^2=67.349$, $d.f. = 1$, $P<0.0001$), W-BR ($\chi^2=19.309$, $d.f. = 1$, $P<0.0001$), and W-N ($\chi^2=67.349$, $d.f. = 1$, $P<0.0001$).

Fewer locusts exhibited hiding behaviour when exposed to GL-N compared to SL-BR ($\chi^2=10.134$, $d.f. = 1$, $P=0.0014$) and W-BR ($\chi^2=4.831$, $d.f. = 1$, $P=0.0279$). More locusts displayed hiding behaviour with GL-N than SL-N ($\chi^2=4.54$, $d.f. = 1$, $P=0.0331$) and W-N ($\chi^2=4.55$, $d.f. = 1$, $P=0.0331$). So, the colour seems to play a supportive role, while the biomimetic shape exerts a more influential effect in eliciting hiding behaviour.

A higher number of locusts showed hiding behaviour when exposed to SL-BR compared to SL-N ($\chi^2=26.579$, $d.f. = 1$, $P<0.0001$) and W-N ($\chi^2=26.58$, $d.f. = 1$, $P<0.0001$). Conversely, fewer locusts exhibited hiding behaviour with

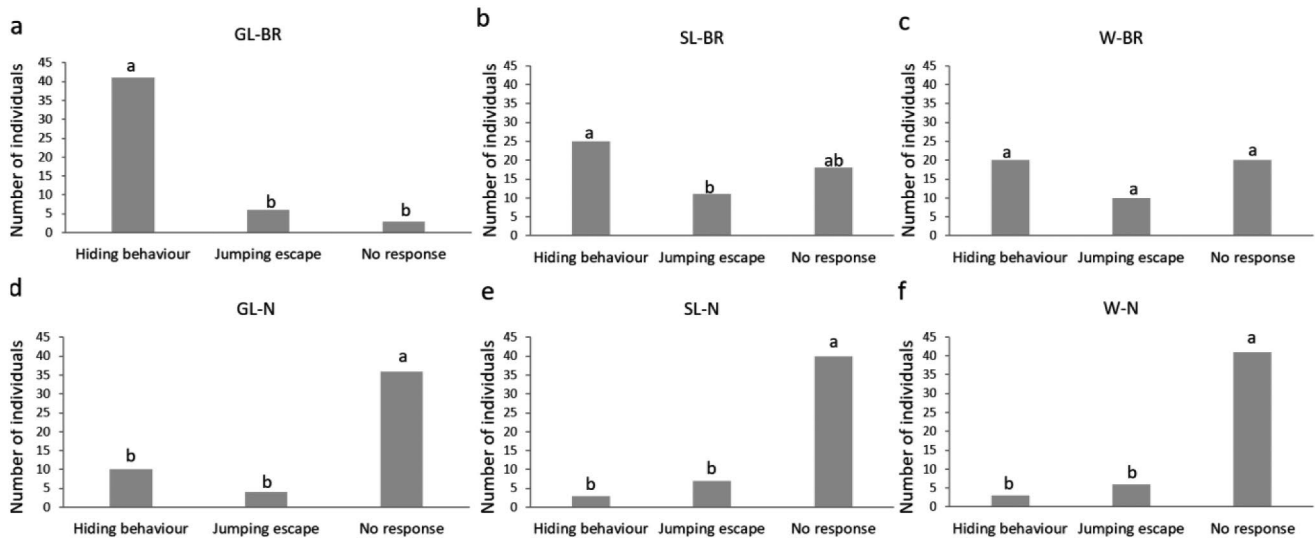


Fig. 4 Number of *Locusta migratoria* individuals performing hiding behaviour, jumping escape, or no response post exposure to gregarious-like biorobotic demonstrator GL-BR **a**, solitary-like biorobotic demonstrator SL-BR **b**, white biorobotic demonstrator W-BR **c**, gre-

garius-like neutral demonstrator GL-N **d**, solitary-like neutral demonstrator SL-N **e**, white neutral demonstrator W-N **f**. Different letters above each histogram indicate significant differences

SL-N compared to W-BR ($\chi^2=26.579$, $d.f. = 1$, $P<0.0001$). More locusts displayed hiding behaviour with W-BR than W-N ($\chi^2=17.857$, $d.f. = 1$, $P<0.0001$), (Fig. 5a).

The number of locusts exhibiting escape jumping behaviour was not significantly affected by the different robotic demonstrators ($\chi^2=5.64$, $d.f. = 5$, $P=0.3428$), (Fig. 5b).

The number of locusts that showed no behavioural response was significantly lower postexposure to GL-BR than postexposure to GL-N ($\chi^2=51.757$, $d.f. = 1$, $P<0.0001$), SL-BR ($\chi^2=14.752$, $d.f. = 1$, $P=0.0001$), SL-N ($\chi^2=63.925$, $d.f. = 1$, $P<0.0001$), W-BR ($\chi^2=17.857$, $d.f. = 1$, $P<0.0001$), and W-N ($\chi^2=67.349$, $d.f. = 1$, $P<0.0001$). The number of locusts that showed no behavioural response was significantly higher postexposure to GL-N than postexposure to SL-BR ($\chi^2=13.351$, $d.f. = 1$, $P=0.0002$), and W-BR ($\chi^2=10.589$, $d.f. = 1$, $P=0.0011$). The number of locusts that showed no behavioural response was significantly lower postexposure to SL-BR than postexposure to SL-N ($\chi^2=20.676$, $d.f. = 1$, $P<0.0001$), and W-N ($\chi^2=22.891$, $d.f. = 1$, $P<0.0011$). The number of locusts that showed no behavioural response was significantly higher postexposure to SL-N than postexposure to W-BR ($\chi^2=17.261$, $d.f. = 1$, $P<0.0001$). The number of locusts that showed no behavioural response was significantly lower postexposure to W-BR than postexposure to W-N ($\chi^2=19.309$, $d.f. = 1$, $P<0.0001$), (Fig. 5c).

Locusts successfully informed by robots showed a significant preference in rotating in the same direction of that of GL-BR (same versus opposite direction: 38 vs. 3; $\chi^2=72.25$, $P<0.0001$), SL-BR (same versus opposite

direction: 23 vs. 2; $\chi^2=68.89$, $P<0.0001$), W-BR (same versus opposite direction: 19 vs. 1; $\chi^2=79.21$, $P<0.0001$), GL-N (same versus opposite direction: 9 vs. 1; $\chi^2=62.41$, $P<0.0001$), SL-N (same versus opposite direction: 3 vs. 0; $\chi^2=98.01$, $P<0.0001$), and W-N (same versus opposite direction: 3 vs. 0; $\chi^2=98.01$, $P<0.0001$) while performing hiding behaviour (Fig. 6).

4 Discussion

Although robust learning has been documented in locusts [43, 51, 52], no findings on their ability to perform socially influenced behaviours were available so far. In previous research attempts, although locusts were suggested to be likely model organisms to show social learning, no socially influenced learning based on feeding on a novel diet previously visited by an experienced conspecific was found [53].

This study demonstrated that social information is used in gregarious *L. migratoria* during predator avoidance contexts. Particularly, locusts were informed by conspecific behavioural displays (in our case by the biorobotic demonstrators) when to exhibit the hiding behaviour. We also noted that biorobotic demonstrators not only socially informed locusts of when to perform hiding behaviour, but also in which direction. Locusts' hiding behaviour is an optomotor reaction occurring when looming visual cues are presented [54], and can be part of a cascade of other behavioural displays such as jumping, dropping, peering. We used robotic demonstrators with different colour patterns and silhouettes

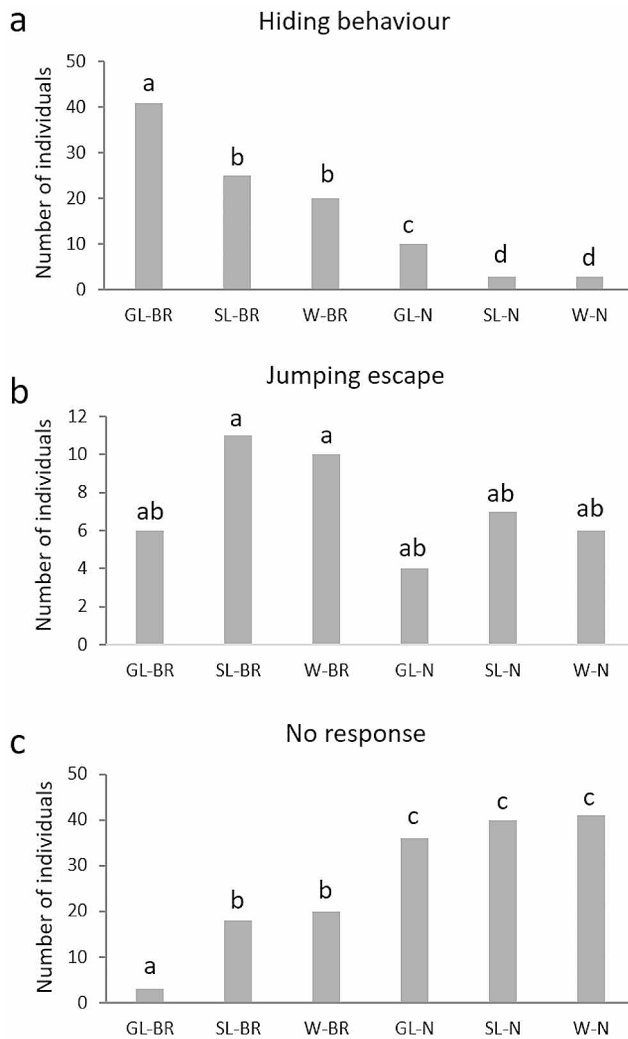


Fig. 5 Number of *Locusta migratoria* individuals performing hiding behaviour **a**, jumping escape **b**, or no response **c** post exposure to different robotic demonstrators. Different letters above each histogram indicate statistically significant differences

to test their effect on social learning, and to make sure that the locust's response was a social imitation of the biorobotic demonstrator behaviour and not an avoidance response to it seen as a potential threat. Locusts are known to be attracted to artificial models of conspecifics [55, 56], and this strengthens our approach in adopting biorobotic demonstrators to investigate social interactions in this species.

We observed a significant impact of the biomimetic silhouette in reducing the latency duration, while colour patterns of robotic (neutral) demonstrators had no effect on that. Also, social learning (e.g. consisting in locusts displaying hiding behaviour after observing it in robotic demonstrators) was significantly promoted by the biomimetic silhouette of biorobotic demonstrators. Social learning has an evolutionary importance enabling a faster spread of novel information than individual learning.

Several studies reported the role that ecological contexts have in fostering social over individual learning [57, 58]. The presence of social information use related to predatory avoidance in *L. migratoria* observed in this study, furtherly indicates how evolution has driven optimization of neural mechanisms underlying anti-predator decision making. In predator-prey contexts, adapting behaviours is crucial for the fitness of a species, thus the selection of a specific behaviour is the result of an accurate costs-benefits calculation [59]. Information acquired via social learning may provide important adaptive advantages for avoiding predators [60]. Although copying the predator avoidance behaviour observed in other conspecifics may waste energy and time with no actual threat, often the benefit of avoiding predation largely exceeds these costs [61].

Another aspect we investigated was the role of colour in triggering social informed hiding behaviour. Gillett [56] investigated the involvement of the conspicuous and complex integument colour pattern of *Schistocerca gregaria* Forskål in social and swarming interactions, by testing albino and normal individuals. However, it has been reported that colour pattern does not play a so important role, but the locust shape was sufficient to promote social aggregations.

Another explanation about the social role of locusts colour pattern is that grouping may be aided by melanin deposits enhancing heat transfer when radiant heat in the field is present [62].

It has also been proposed that the colour pattern can support the cohesion of the group via optomotor behaviours and visual compensation [63].

Herein, a significant impact of colour patterns in triggering different behavioural responses in locusts was observed. Socially induced hiding behaviour was especially evident when the gregarious-like colour pattern was in conjunction with the silhouette of the biorobotic demonstrator (GL-BR). So, colour pattern, among other different social functions [56, 62–65], may also have a relevant role in social information and social learning in locusts.

Overall, this study indicates gregarious locusts use social information and this is ecological context-dependent, adding basic knowledge on the complex behavioural ecology and social biology dynamics of such organisms. In addition, the proposed animal-robot interaction paradigm has shown the potential of robots as carrier of social information to living organisms in order to influence their behaviour and decision making process. These findings can pave the way to robotics-based methods of non-invasive environmental management [66–69], and social biology investigation.

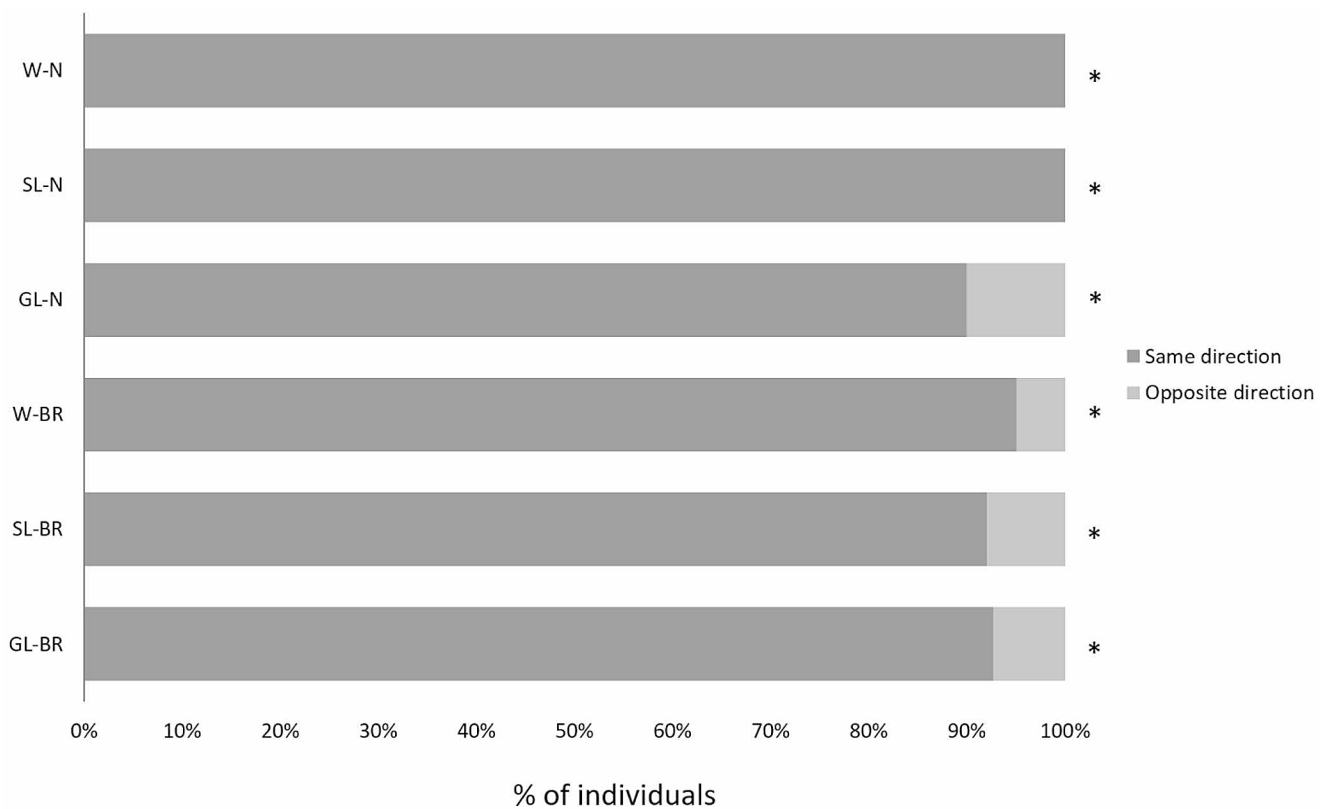


Fig. 6 Percentage of *Locusta migratoria* individuals performing hiding behaviour on the same versus opposite direction of that of different robotic demonstrators. Asterisks (*) indicate statistically significant preferences

5 Conclusion

This study reveals the role of social robotics and biohybrid complex networks in promoting current research on social learning.

Although invertebrates, with their relatively simple nervous system, may be models particularly suited to investigate the evolution and mechanisms of social learning, it has been poorly investigated in these organisms so far. Findings reported in this insect-robot interaction research provide important information on social learning processes that can be reflected in other animal species, including humans. Gregarious locusts were observed to perform social-influenced behaviours in specific ecological contexts, and biomimetic silhouette and colour patterns had a significant impact in triggering different social responses. The proposed animal-robot interaction paradigm provides basic knowledge on social biology and behavioural ecology, placing social robotics as elective approach for these lines of research.

Acknowledgements This study is dedicated to Vito Romano. The authors would like to thank Dr. Francesco Inglese and Mr. Godfried Jansen van Vuuren for their kind assistance during the experiments.

Funding Open access funding provided by Scuola Superiore Sant'Anna within the CRUI-CARE Agreement. This research was carried out in the framework of the EU HORIZON PATHFINDEROPEN Project ‘SENSORBEES— Sensorbees are ENhanced Self-ORGanizing Biohybrids for Ecological and Environmental Surveillance’ [101130325], and the PRIN Project “COSMIC— Controlled Space Microecological system supporting eCopoiesis” [2022EY5BXC]. The funders had no role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript. Open access funding provided by Scuola Superiore Sant'Anna within the CRUI-CARE Agreement.

Declarations

Ethical Approval This study was carried out in accordance with the Guidelines for the Use of Animals in Research, and the 7010–2020— IEEE Recommended Practice for Assessing the Impact of Autonomous and Intelligent Systems on Human Well-Being, as well as the legal requirements of Italian and EU legislation. All experiments consisted in behavioural tests, and no specific permits are needed in the country where the experiments were conducted.

Competing Interests We declare we have no competing interest.

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