Immunization against social fear learning

Armita Golkar* & Andreas Olsson

Karolinska Institutet, Department of Clinical Neuroscience, Psychology section

*Correspondence should be addressed to:

Armita Golkar

Karolinska Institutet

Department of Clinical Neuroscience, Psychology Section

17177 Stockholm, Sweden

Tel: +46 852482455, fax: +46 8 30 72 98

Email: armita.golkar@ki.se

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Abstract

Social fear learning offers an efficient way to transmit information about potential threats, little is known, however, about the learning processes that counteract the social transmission of fear. In three separate experiments, we found that safety information transmitted from another individual (i.e. demonstrator) during pre-exposure prevented subsequent observational fear learning (Experiment 1-3), and this effect was maintained in a new context involving direct threat confrontation (Experiment 3). This protection from observational fear learning was specific to conditions in which information about both safety and danger was transmitted from the same demonstrator (Experiment 2-3), and was unaffected by increasing the number of the safety demonstrators (Experiment 3). Collectively, these findings demonstrate that observational pre-exposure can limit social transmission of fear. Future research is needed to better understand the conditions under which such effects generalize across individual demonstrators.

Keywords: Social learning, safety, fear conditioning, exposure, latent inhibition

Learning about emotional events by observing the actions of other individuals is ubiquitous in human culture. Such social learning has served adaptive purposes throughout human evolution and offers an efficient route to learn which stimuli are dangerous and which are safe. However, in spite of a growing understanding of the mechanisms underlying social transmission of fear (Olsson & Phelps, 2007), little is known about the processes involved in social transmission of safety. This is surprising given that much of the information conveyed between individuals involves informing about what is safe and harmless. For example, socially transmitted safety information is an important factor in parent modeling, during which children learn appropriate behaviors by observing the actions of their parents (Bandura, 1977), but less is known about how previously learned safety information can influence and determine subsequent social learning. Here, we address how socially transmitted safety information acquired through observation can protect against social transmission of fear in healthy adults.

Research on both human and non-human primates (e.g. Hygge & Öhman, 1978; Mineka, Davidson, Cook, & Keir, 1984; Olsson & Phelps, 2004) demonstrates that acquisition of fear through observation shares several features with directly acquired fear (Askew & Field, 2008; Hooker, Verosky, Miyakawa, Knight, & D'Esposito, 2008; Kelly & Forsyth, 2009; Olsson, Nearing, & Phelps, 2007; Olsson & Phelps, 2004). Thus, like directly learned fear, socially transmitted fear can be expressed without conscious awareness (Olsson & Phelps, 2004), develops rapidly after only a few exposures (Mineka et al., 1984), and contributes to the etiology of fear-related anxiety disorders (Rachman, 1977). One implication of the potency of social fear learning is that fears are readily transmitted between individuals living in close proximity (Laland, 2004) and clinical observations suggest that parental modeling contributes to the elevated rates of transmission of anxiety disorders from parents and children (Askew & Field, 2008; Craske, 2003). However, little is known about the learning processes that counteract or reduce the social transmission of fears. One possible route may be via social safety

experiences. For instance, although social transmission of fear between individuals living in close proximity occurs readily, a proportion of such fears may be extinguished through observational safety learning experiences, which serve as a particularly efficient form of safety learning (Bandura, Grusec, & Menlove, 1967; Golkar, Selbing, Flygare, Öhman, & Olsson, 2013). Indeed, observational safety procedures are commonly exploited as a part of exposure treatment of fear-related anxiety disorders to optimize safety learning (Seligman & Wuyek, 2005). An alternative explanation is that social transmission of fear is counteracted by safety learning *prior to* observational fear learning. Indeed, prior exposure to a stimulus presented alone results in a retardation of subsequent conditioning to that stimulus, a phenomenon known as *latent inhibition* (Lubow, 1973). Although the effects of latent inhibition have long been documented using classical conditioning procedures, less is known about the possibility to prevent the social transmission of fear through prior observational safety exposure. In an attempt to evaluate the influence of prior observational stimulus exposure, Mineka and Cook (1986) reported that rhesus monkeys receiving prior exposure to a non-fearful monkey interacting with a snake (i.e. observational pre-exposure) were less likely to observationally acquire fear of snakes compared to conditions in which the monkeys received the same amount of direct exposure to snakes only (i.e. direct pre-exposure), or watched another monkey behaving non-fearfully with a neutral object. This superior effect of prior observational exposure was referred to as "immunization". To date, no study has directly addressed the processes by which socially transferred information determines subsequent learning from another individual in humans.

In order to investigate the learning processes that are likely to prevent social transmission of fear, we performed the following experiments. In Experiment 1, we directly contrasted the effects of observational and direct safety exposure on subsequent observational fear learning. We hypothesized that, if prior exposure to a non-fearful demonstrator is more effective than

prior stimulus exposure alone, then the group receiving observational pre-exposure will show less expression of conditioned fear during the observational fear learning task compared to the group that received prior stimulus exposure only. In two follow-up experiments (Experiment 2-3), we further characterized the boundary conditions of this immunization effect. More specifically, we investigated the generalizability of the effect by addressing if safety information transferred from one individual prevented fear learning from a different individual (Experiment 2) and whether the protective effects of observational pre-exposure were maintained in a new context (Experiment 3).

Experiment 1

Based on sample sizes in previous research on vicarious learning (Olsson et al., 2007; Golkar et al., 2013), we planned to include 40 participants in Experiment 1. Of the 44 participants that completed Experiment 1, we excluded four participants that failed to report the correct contingency between the conditioned stimulus (CS) and the unconditioned stimulus (US), as assessed during a post-experimental interview, and three outliers because their skin conductance responses (SCRs) were above/below 3 standard deviations of the mean in the pre-exposure or acquisition stage. This left 37 participants (27 females; mean age = 23.4 years, SD = 5.63) in the final sample (Same-demonstrator: n = 20; No-demonstrator: n = 17).

The experiment was divided into two stages; pre-exposure and acquisition (Figure 1, Table 1). During pre-exposure, the Same-demonstrator group watched a video in which a calm male demonstrator watched non-reinforced presentations of two angry male faces (the CSs). The video for the No-demonstrator group was identical but without the demonstrator. In the acquisition video, four presentations of one of the CSs (CS+) were reinforced with a shock given to the demonstrator's wrist. The other CS (CS-) was never reinforced. During both stages,

each CS was presented 6 times with a duration of 6s. Between each CS trial, a black screen was presented for 12-18s (Supplementary methods).

-- Insert Figure 1 and Table 1 here ---

The conditioned response (CR) was indexed as the differential SCR to the CS+ and CS- (Supplementary methods). The mean CR from Experiment 1 and 2 are displayed in Figure 2. As expected, a 2 (CS+, CS-) x 2 (Same-demonstrator, No-demonstrator) repeated-measures ANOVA revealed no significant effects of stimuli (Main effect of CS: $F(1,35) = 1.83$, $p = .19$) or differences between groups (CS x Group $F(1,35) = .24$, $p = .63$; during the initial pre-exposure stage. The predicted group-differences emerged during the observational acquisition stage (Stimulus x group: $F(1,35) = 5.22$, $p = .028$, $\eta^2 = .12$). Planned follow-up t-tests confirmed that that the Same-demonstrator group acquired significantly less CS+/CS- differentiation than the No-demonstrator group ($t(35) = 2.29$, $p = 0.028$, 95% CI = [-0.37, -0.02]). Thus, only the No-demonstrator group that received CS pre-exposure in the absence of the demonstrator showed successful fear acquisition, as indexed by a significantly higher response to the CS+ compared to the CS- ($t(16) = 2.75$, $p = .014$; 95% CI = [0.036, 0.276]), whereas this effect was not significant in the Same-demonstrator group that received pre-exposure with the demonstrator ($t(19) = .63$, $p = .533$; 95% CI = [-0.17, 0.09]).

Experiment 2

Experiment 1 showed that compared to direct CS pre-exposure, observational CS pre-exposure prevented subsequent observational fear acquisition. To address the generalizability of this effect, Experiment 2 used the same procedure as in Experiment 1, with the following changes. First, we replaced the CSs (an image of a snake served as the CS+, and an image of a spider served as the CS-) and the demonstrator. Second, to address whether observational CS pre-exposure generalized across different individual demonstrators, we compared an

observational pre-exposure group presented to the same male demonstrator during both pre-exposure and fear acquisition (as in Experiment 1) with a group that was exposed to a novel, male demonstrator during fear acquisition. Which demonstrator that served during pre-exposure and which served during observational fear acquisition was counterbalanced across participants.

Of the 45 participants that completed the experiment, we excluded three outliers because their SCRs were above/below three standard deviations of the mean during the pre-exposure or acquisition stages, and one participant that erroneously reported receiving shocks during the experiment. This left 41 participants (15 female, mean age = 25.5 years, SD = 6.72) in the final sample (Same-demonstrator: n = 21; Different-demonstrator: n = 20).

There were no significant effects of stimuli (Main effect of CS: $F(1,39) = .01$ $p = .99$) or CS x Group interaction ($F(1,39) = .25$, $p = .62$) during the pre-exposure stage. Group-differences emerged during the observational acquisition stage (CS x Group: $F(1,39) = 5.17$, $p = .029$, $\eta^2 = .11$) and planned comparisons confirmed that CS+/CS- differentiation was less pronounced in the Same-demonstrator group compared to the Different-demonstrator group ($t(39) = 2.27$, $p = 0.029$, 95% CI = [-0.55, -0.03]). Successful fear acquisition was only evident in the Different-demonstrator group ($t(20) = 3.26$, $p = .01$; 95% CI = [0.05, 0.44]), and was not significant in Same-demonstrator group ($t(19) = .06$, $p = .95$; 95% CI = [-0.20, 0.19]), replicating the immunization effect from Experiment 1.

-- Insert Figure 2 here --

Experiment 3

Experiment 2 demonstrated that the immunization effect was reproducible using a new set of stimuli and demonstrators, but restricted to conditions in which information about safety and danger was transmitted from the same demonstrator. If the protective effect of immunization, once established, is maintained, this effect should critically be demonstrated in

a new context. Therefore, the design of Experiment 3 was identical to that of Experiment 2, with the addition of a test stage during which participants were re-exposed to six non-reinforced presentations of each of the two CSs in the absence of a demonstrator. Moreover, we also included a group that was exposed to multiple demonstrators during the pre-exposure stage. This group was included to address whether the addition of a pre-exposure demonstrator would enhance safety learning, similar to related work in which safety exposure involving multiple demonstrators have been shown to enhance the effects of model-based exposure treatments (Bandura et al., 1968). To this end, participants in the Multiple-demonstrator group were exposed to two different demonstrators during pre-exposure; the first demonstrator watched the first half of the unreinforced CS presentations (three presentations/CS) and the second demonstrator watched the remaining three presentations/CS. The order with which the demonstrators appeared was counterbalanced across participants and both the Multiple- and Different-demonstrator group were exposed to a novel demonstrator during the observational fear learning stage.

Of the 70 participants that completed the experiment, we excluded four participants that failed to report the correct CS-US contingency, and two participants due to technical problems. This left 64 participants (40 female, mean age = 25.2 years, SD = 5.00) in the final sample (Same-demonstrator: n = 23; Different-demonstrator: n = 22; Multiple-demonstrators: n = 19). A 2 x 3 repeated-measures ANOVA revealed no significant effects during the pre-exposure stage (Main effect of CS: $F(1,61) = .59$, $p = .45$; CS x Group $F(2,61) = .36$, $p = .68$). Although the group differences were not significant during the observational acquisition stage (CS x Group: $F(2,61) = 1.90$, $p = .18$) planned comparisons revealed that fear acquisition was significant in the Different-demonstrator group ($t(21) = 2.38$, $p = .03$; 95% CI = [0.04, 0.60]), marginally significant in the Multiple-demonstrator group ($t(18) = 1.18$, $p = .087$; 95% CI = [-0.03, 0.46]), and, again replicating Experiments 1-2, not significant in Same-demonstrator

group ($t(22) = .87$, $p = .40$; 95% CI = [-0.12, 0.30]). Importantly, we observed a significant CS x Group interaction during the direct test stage ($F(2,61) = 5.00$, $p = .01$, $\eta^2 = .11$). This interaction was driven by less CS+/CS- differentiation in the Same-demonstrator group compared to the Different-demonstrator group ($t(43) = 2.17$, $p = .036$; 95% CI = [-0.857, 0.30]) and the Multiple demonstrator group ($t(40) = 3.22$, $p = .003$; 95% CI = [-1.045, 0.239]), whereas the Different-demonstrator and the Multiple demonstrator groups did not differ ($t(39) = .089$, $p = .377$). Thus, immunization in the Same-demonstrator group generalized to the direct test situation in which the demonstrator was absent ($t(22) = .28$, $p = .78$; 95% CI = [-0.23, 0.31]), whereas CS+/CS- differentiation was maintained in the Different- ($t(21) = 3.02$, $p = .01$; 95% CI = [0.15, 0.81]) and Multiple-demonstrator groups ($t(18) = 4.45$, $p < .001$; 95% CI = [0.81, 0.99) (Figure 3).

--Insert Figure 3 here --

Finally, to provide an estimate of the immunization effect obtained across Experiment 1-3, we followed previous recommendation (e.g. Braver, Thoemmes, & Rosenthal, 2014) and conducted an internal meta-analysis (Borenstein, 2009; www.meta-analysis.com). We computed the effect size and its 95% confidence interval for the individual studies by taking the mean acquisition differences (CS+/CS- difference in Same-demonstrator vs. No/Different-demonstrator group) and dividing them by the pooled standardized difference (Cohen's d). A positive effect size indicates less CS+/CS- differentiation in the Same-demonstrator group (i.e. favors the immunization effect). The averaged standardized mean difference for the immunization effect was $d = 0.611$, 95% CI [-0.248, 0.973], Z = 3.302, $p = .001$ (Supplementary Figure 1). Post-hoc power computations showed that the meta-analysis achieved a power of 92% to detect an effect of this size, supporting that pre-exposure to the same demonstrator retards observational fear learning.

DISCUSSION

Both experimental (Golkar et al., 2013; Olsson & Phelps, 2007) and clinical research (Rachman, 1977) highlight that social leaning serves a central role in the development and treatment of fear-related anxiety disorders. What is unknown is whether there are practical ways to directly immunize against the acquisition of anxiety disorders, such as, specific phobias. Here, we demonstrated that social transmission of fear could be prevented by prior social safety exposure. Participants that observed another individual (demonstrator) behaving non-fearfully in the presence of the CSs did not acquire significant levels of conditioned fear towards the CS+ during the observational conditioning stage, and this effect was maintained during direct threat confrontation in a novel test context. Importantly, observational pre-exposure prevented observational fear learning when information about both safety and danger was transmitted from the same individual demonstrator. The specificity of this effect suggests that the contextual similarity between the pre-exposure and the acquisition stage is critical to establish the immunization effect. This contextual dependency of observational pre-exposure is predicted from other forms of non-reinforced exposure, including latent inhibition and extinction. For example, latent inhibition is typically disrupted by a change of context between pre-exposure and acquisition (Gray et al., 2001; Westbrook, Jones, Bailey, & Harris, 2000), but when pre-exposure and acquisition occurred in the same context, latent inhibition was insensitive to contextual changes that first occurred at test (Sanjuan Mdel, Alonso, & Nelson, 2006; Westbrook et al., 2000). Similarly, the loss of CS responding that accompanies extinction learning is highly context specific as revealed by post-extinction phenomena such as renewal during which extinguished CRs reappear due to a change of context (Bouton, 2002). However, human extinction studies have failed to demonstrate renewal in a novel test context when the preceding fear and safety learning contexts were held constant (i.e. AAB design) (Vansteenwegen et al., 2005; Vervliet, Vansteenwegen, & Eelen, 2004). Both these phenomena

parallel the findings of Experiment 3, during which CRs were maintained at a low level in the Same-demonstrator group despite the context shift introduced during the test stage.

Previous work suggests that increasing contextual diversity during post-acquisition exposure provides a larger number of contextual cues to be associated with safety learning, thereby promoting generalization of this learning to other contexts (Gunther, Denniston, & Miller, 1998; Vansteenwegen et al., 2007; but see Bouton et al, 2006; Neumann et al., 2007). In humans, post-acquisition safety exposure conducted with multiple demonstrators (in combination with increased diversity of the CSs) enhanced the effects of safety exposure as compared to a single demonstrator procedure (Bandura & Menlove, 1968), suggesting that safety information acquired from multiple demonstrators may similarly enhance the generalizability of pre-acquisition safety learning. In the present study, merely increasing the number of safety demonstrators during pre-exposure did not immunize against observational fear learning from a novel demonstrator, lending support to the fact that the efficacy of immunization procedure is governed by contextual cues including the identity of the demonstrator and the CS. It is unclear from the present work whether adding more than one safety demonstrator could have facilitated generalization across demonstrators, or if combining multiple models with a larger number of exposure trials could enhance the protective effects of observational pre-exposure.

An intriguing possibility is that the generalization of safety learning between different individual demonstrators depends on other factors such as familiarity and social group membership. Indeed, humans have an evolved capacity to quickly categorize other individuals into social groups to distinguish between those that belong to one's own group (in-group) and those outside of one's group (out-group) (Allport, 1954; Kurzban, Tooby, & Cosmides, 2001). Recently, both observational fear and safety learning was demonstrated to be superior when learning occurred from a demonstrator belonging to a racial in-group as compared to an out-

group (Golkar, Castro, & Olsson, 2015). Similar effects have been reported in rodents in which the strength of observational fear learning is enhanced by relatedness (Jeon et al., 2010; Kavaliers, Colwell, & Choleris, 2005), familiarity, and social status (Kavaliers et al., 2005). Future studies should address whether the immunization effect reflects a social effect that similarly is influenced and determined by factors such as familiarity and social group membership. For example, such effects might help to understand if safety information acquired from familiar members more easily protects against fear learning from other, unfamiliar individuals in more ecologically valid settings when information flow between related and familiar individuals, such as children, parents, and peers.

In sum, we found that social safety learning provided stronger protection against subsequent social fear learning than did directly transmitted safety information, and that the protective effect of prior safety learning was maintained during direct threat confrontation in a novel context. These findings may help develop practical strategies to prevent the onset of fear-related anxiety disorders in particularly exposed and vulnerable groups of individuals. To more fully understand the processes that govern when and from whom such strategies may provide useful, future research should address whether social information provides a safety cue beyond what is provided by context only, and if so, how social factors such as familiarity and group membership, influence the generalizability of socially transmitted safety information across individuals.

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Table 1. Summary of the experimental manipulations across Experiment 1-3.

	Group	Pre-exposure demonstrator	Acquisition demonstrator	Test (only Experiment 3)
Experiment 1	Same	A	A	
	No	No	A	
Experiment 2	Same	A	A	
	Different	B	A	
Experiment 3	Same	A	A	No
	Different	B	A	No
	Multiple	B + C	A	No

Note. We assessed the effect of observational pre-exposure in the Same-demonstrator group on fear acquisition (Experiment 1-3) and test (Experiment 3), compared to a No-demonstrator group (Experiment1), a Different-demonstrator group (Experiment 2-3) or a Multiple-demonstrators group (Experiment3). Same = Same-demonstrator, No = No-demonstrator, Different = Different-demonstrator, A, B, C denotes the identity of the demonstrator.

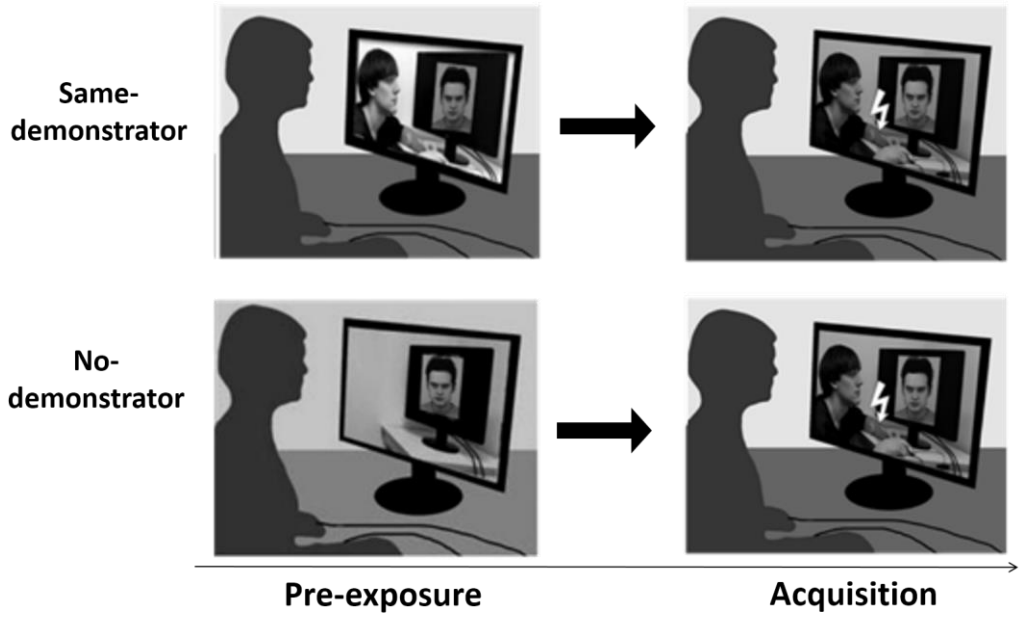
Figure legends

*Figure 1***.** Design of Experiment 1. During the pre-exposure stage, the video for the Same-demonstrator group contained a calm male demonstrator sitting in front of the screen watching unreinforced CS presentations. Apart from the addition of the demonstrator, the video for the No-demonstrator group was identical in terms of content and timing. The observational acquisition video was identical in both groups. In the video, four out of six presentations of one of the CSs (CS+) co-terminated with a 100-ms shock given to the wrist of the demonstrator who twitched his arm in response to receiving the shock. The six presentations of the other CS (CS-) were never paired with a shock.

Figure 2. Observational pre-exposure effectively prevented fear learning. (A) In Experiment 1, Observational CSs pre-exposure prevented subsequent observational fear acquisition in the Same-demonstrator group compared to the No-demonstrator group receiving direct CS exposure only. (B). In Experiment 2, we replicated this effect in a group exposed to the same individual demonstrator during both pre-exposure and fear acquisition (Same-demonstrator group), but the effect of observational CS pre-exposure did not protect against observational fear acquisition from a different individual (Different-demonstrator group). Error bars indicate standard error of the mean, * = significant differences. CR = conditioned response (CS+ > CS- SCR difference).

Figure 3. Observational pre-exposure prevented fear learning in the Same-demonstrator group and this protective effect generalized to a direct test context. Changing the identity of the demonstrator between pre-exposure and acquisition stages did not prevent observational fear learning in the Different-demonstrator group and in the group exposed to Multiple pre-exposure

demonstrators. Error bars indicate standard error of the mean, * = $p < .05$, # = $p < .09$. CR = conditioned response (CS+ > CS- SCR difference). Same = Same-demonstrator, Different = Different-demonstrator, Multiple = Multiple-demonstrators.


Same-
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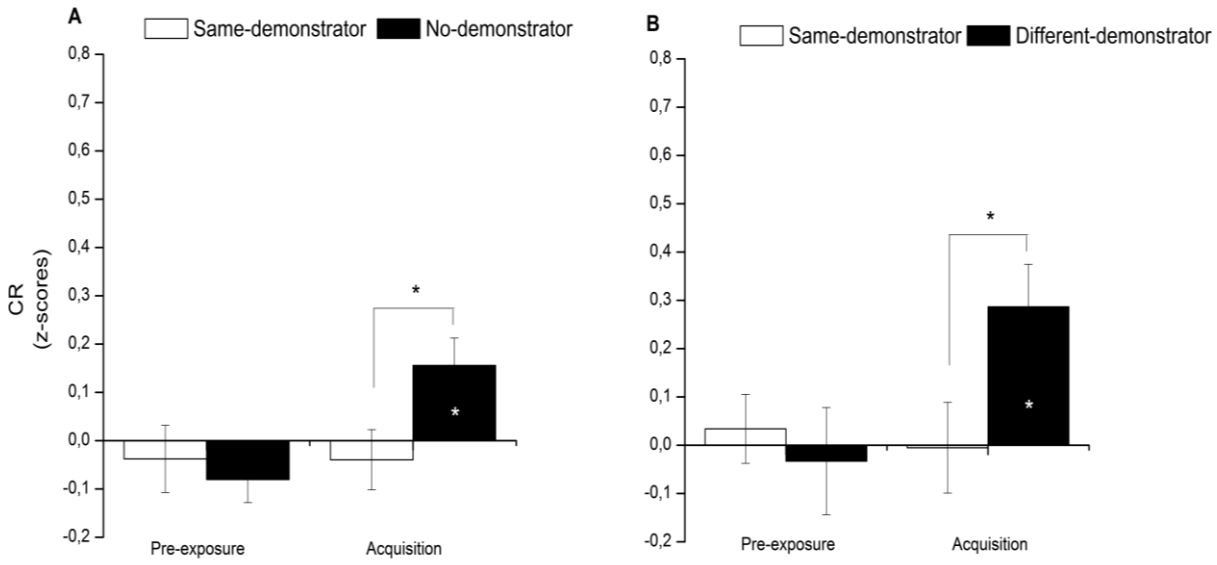
A
Same-demonstrator
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CR
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0,3
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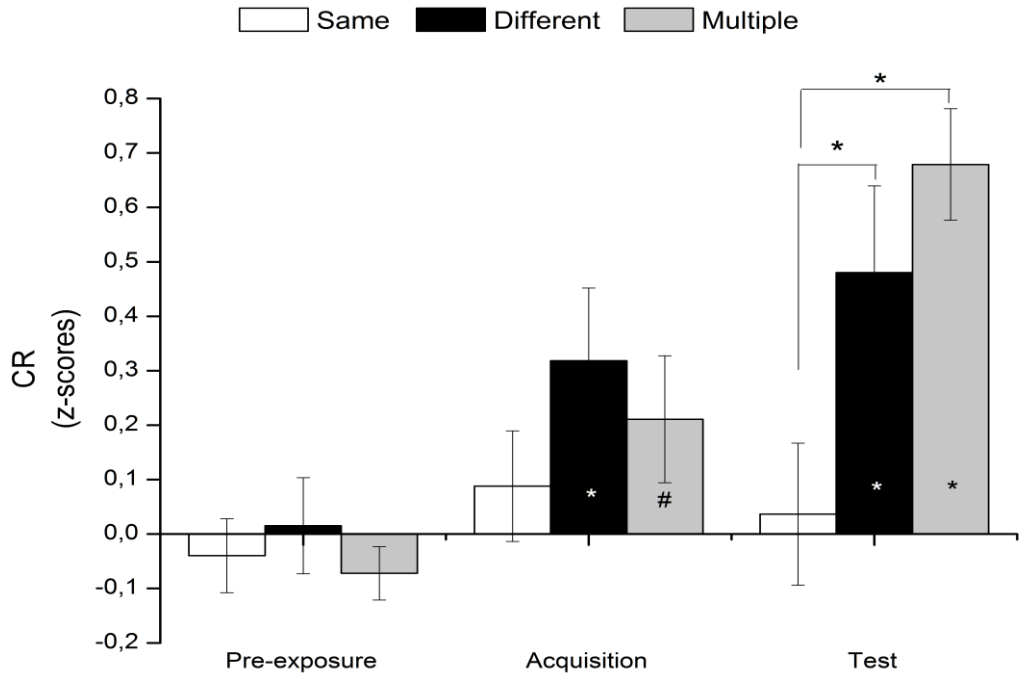
0,1
0,0
-0,1
-0,2
*
*
Pre-exposure
Acquisition
B
Same-demonstrator
Different-demonstrator
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0,0
-0,1
-0,2
*
*
Pre-exposure
Acquisition


Same
Different
Multiple
CR
(z-scores)
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0,0
-0,1
-0,2
*
*
*
*
*
#
Pre-exposure
Acquisition
Test