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No fear no risk! Human risk behavior is affected by chemosensory anxiety signals

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ABSTRACT

An important aspect of cognitive functioning is decision-making, which depends on the correct interpretation of emotional processes. High trait anxiety has been associated with increased risk taking behavior in decision-making tasks. An interesting fact is that anxiety and anxiety-related chemosignals as well as decision-making share similar regions of neuronal activation. In order to ascertain if chemosensory anxiety signals have similar effects on risk taking behavior of healthy participants as high trait anxiety we used a novel computerized decision-making task, called Haegler's Risk Game (HRG). This task measures risk taking behavior based on contingencies and can be played repeatedly without a learning effect. To obtain chemosensory signals the sweat of 21 male donors was collected in a high rope course (anxiety condition). For the chemosensory control condition sweat was collected during an ergometer workout (exercise condition). In a double-blind study, 30 healthy recipients (16 females) had to play HRG while being exposed to sweat samples or empty control samples (control condition) in three sessions of randomized order. Comparison of the risk taking behavior of the three conditions showed significantly higher risk taking behavior in participants for the most risky choices during the anxiety condition compared to the control conditions. Additionally, recipients showed significantly higher latency before making their decision in the most risky choices during the anxiety condition. This experiment gives evidence that chemosensory anxiety signals are communicated between humans thereby increasing participants' risk taking behavior.

1. Introduction

Anxiety induces physiological responses, like an increase in sweating, heart rate, or muscular tension, as well as behavioral responses, which can either be a fight, flight, or freeze reaction (Ackerl, Atzmueller, & Grammer, 2002). Some animals and man react with an increase others with a decrease in caution, response time, adjustment to their environment, as well as with the ability to conceive relationships between properties of uncertain situations when receiving a threat through sensory channels (Koolhaas et al., 1999). Anxiety-related chemosignals released by an animal can trigger conspecifics to either escape or accumulate to attack a common enemy (Valenta & Rigby, 1968).

Until now anxiety-related chemosignals are well established in animals including mammals (Egan et al., 2009; Gerlai, 2010; Hauser et al., 2008; Kiyokawa, Kikusui, Takeuchi, & Mori, 2004; Kiyokawa, Shimozuru, Kikusui, Takeuchi, & Mori, 2006; Speedie & Gerlai, 2008), while research is still at the beginning of exploring anxiety chemosignals in humans (Ackerl et al., 2002; Chen & Haviland-Jones, 2000; Mujica-Parodi et al., 2009; Pause, Adolph, Prehn-Kristensen, & Ferstl, 2009; Pause, Ohrt, Prehn, & Ferstl, 2004; Prehn, Ohrt, Sojka, Ferstl, & Pause, 2006; Zhou & Chen, 2009). Previous findings demonstrate that women perform more accurately on a word-association task, and had a slower response time in word pairs containing ambiguous content when exposed to chemosensory anxiety signals (Chen, Katdare, & Lucas, 2006).

In the present study we explored if anxiety-related chemosignals derived from a visit in a high-rope course change the willingness to take a risk using a novel decision-making task, called Haegler's Risk Game (HRG). Decision-making, i.e. choosing one out of several alternatives with an uncertain outcome, consists of several cognitive processes. One important aspect of decision-making is risk taking which is defined as the tendency of preferring

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an action with a possible large profitable or harmful outcome, although unlikely, over an alternative action with a small profitable more likely outcome. In essence, risk taking can be subdivided into anticipation, award, and penalty-related processing (Paulus, Rogalsky, Simmons, Feinstein, & Stein, 2003).

Existing decision-making tasks like, e.g. Iowa Gambling Task (IGT), Risk Task, or Gamble Task (Bechara, Damasio, Damasio, & Anderson, 1994; Rogers, Everitt, et al., 1999; Rogers, Owen, et al., 1999) have been utilized in several functional magnetic resonance imaging (fMRI) studies. Neural substrates being involved in real-life decision-making, more precisely in high risk behavior, showed brain activation in amygdala, thalamus, cingulate cortex, dorsolateral prefrontal cortex, cerebellum, and anterior insula (Bush et al., 2002; Doya, 2008; Ernst et al., 2002; Paulus et al., 2003; Rogers et al., 2004; Thut et al., 1997). Some of these brain areas were also activated in patients with anxiety disorders, for example amygdala, cingulate cortex, and medial prefrontal cortex (Bishop, Duncan, Brett, & Lawrence, 2004; Etkin et al., 2004; Paulus, Feinstein, Simmons, & Stein, 2004; Simpson, Drevets, Snyder, Gusnard, & Raichle, 2001). Just recently, effects of anxiety-related chemosignals were analyzed using fMRI. Activation patterns were found in amygdala, cerebellum, precuneus, fusiform gyrus, insula, cingulate cortex, thalamus, dorsomedial prefrontal cortex, and vermis (Mujica-Parodi et al., 2009; Prehn-Kristensen et al., 2009) when healthy participants were exposed to chemosignals of anxiety. Therefore, it could be speculated that anxiety as well as the perception of chemosignals of anxiety affect decision-making at an emotional as well as at a cognitive level. Lately, two studies investigated the effects of high trait anxiety on decision-making (de Visser et al., 2010; Miu, Heilman, & Houser, 2008). Both studies reported that participants with high trait anxiety showed a higher risk taking behavior when playing IGT than normal participants, which emphasizes a possible relationship between anxiety and decision-making.

A crucial drawback of existing decision-making tasks is that they cannot be executed repeatedly without excluding a learning effect. Therefore, in the current study we introduced a novel computerized decision-making task in which participants have to make decisions between contingencies. Due to the lack of a winning strategy, a participant can play HRG repeatedly without a learning effect. In our study each participant played the game three times, i.e. once during each of the three different stimulation conditions (anxiety, exercise, control condition), while their risk taking behavior as well as the response time was monitored.

2. Material and methods

The local Medical Ethics Review Committee of our University approved the entire study, which was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained by all participants.

2.1. Participants

2.1.1. Sweat donors

A total of 21 healthy male nonsmokers (age: mean 28.3 years, SD 7.9 years) attended in both sweat donation sessions (exercise, anxiety). None of the participants took any medication or had any disease. They were exclusively heterosexual determined on a 7-point scale (mean 0.0, SD 0.0) (Kinsey, Pomeroy, Martin, & Gebhard, 1953). Donors were screened using the Spielberger's state-trait anxiety inventory (STAI X (Spielberger, Gorsuch, & Lushene, 1970), German version by Laux, Glanzmann, Schaffner, and Spielberger (1981)). This test consists of two subtests for obtaining how participants feel in general (trait anxiety, STAI X2) and how they feel at a specific moment (state anxiety, STAI X1), while each scale is composed of 20 items. Donors had a normal anxiety level with a mean trait anxiety score of 31.7 (SD 6.2). The donors answered the STAI X1 during both sweat assessments at several time points.

2.1.2. Pilot study

In a pilot study 50 healthy participants (25 females; age: mean 33.1 years, SD 11.5 years) were instructed to play Haegler's Risk Game in the absence of olfactory stimuli. No sex-differences in age were present (independent two-sample t-test: $t(48) = 0.53$, p = not significant [n.s.]) and none of the participants took part in the main experiment.

2.1.3. Sweat recipients

Thirty healthy participants (16 females; age: mean 31.7 years, SD 8.4 years) took part in the main experiment. All recipients were normosmic, their sense of smell was tested using the Sniffin' Sticks Battery (Hummel et al., 1996) (TDI: mean 35.6, SD 2.3). They were not taking any medication known to interfere with the olfactory system (Doty & Bromley, 2004; Schiffman, 1994), and none of them reported any olfactory disturbances. Recipients were instructed to fill in the STAI X2 questionnaire (Laux et al., 1981). All of them showed a normal anxiety level with a mean trait anxiety score of 38.0 (SD 8.4). Female participants reported neither to be pregnant nor to lactate. No sex-differences were found, neither for age, nor for STAI X2 or TDI score (all independent two-sample t-tests with $t(28) < 1.10$, p = n.s.).

2.2. Sweat sampling procedure

The sweat sampling procedure was part of a larger study on chemosensory anxiety signals. Two days before either sweat collection as well as on the day of both sweat donations, donors were instructed to follow a certain dietary and behavioral procedure. They were not allowed to use any odorous toiletry (deodorants/antiperspirants, perfumes, aftershaves, perfumed shower gels, or body lotions). Two days before the sweat donation they could shower as often as they wanted using an odorless shower gel (Balea, Ultra Sensitive, dm-dogerie markt, Karlsruhe, Germany) provided by the instructors. They were instructed not to attend a swimming pool due to the chlorine in the water, not drink alcohol or eat food containing garlic, onions, hot spices, or asparagus. The evening before the sweat sampling they should take a shower and wear only loose, odorless clothes until the sweat sampling. On either day of the sweat samplings donors were only allowed to wash their armpits with pure water.

During the exercise condition donors had to ride a bicycle ergometer twice for 30 min (run 1, run 2), respectively, with a power of 120 W and 90 revolutions per minute, having a 15 min break in between the two runs. The workout took place in the Department of Physiotherapy of our institution.

In the anxiety condition donors had to attend a high rope course (www.hochseilgartenundmehr.de). During this visit they had to overcome two different challenges lasting approximately 30 min each with a 15 min break in between. The first challenge was a parcour consisting of five demanding tasks at an altitude of nine meters. First they had to balance free-hand over a *beam*, followed by a walk over a *tremor bridge*, third they crossed a swinging *double beam* without holding on, forth they had to do the *flea jump*, and finally they were instructed to climb along a *cargo net*. In the second challenge, called the *pamper pole*, donors had to climb a pole, which was 7 m tall. Their task was to stand free-hand at the top of the pole for a short period of time.

Fresh cotton pads (16 cm × 5.5 cm) were attached to both armpits during each session (exercise run 1, exercise run 2, anxiety parcour, anxiety pole) covered by tight white cotton long-sleeve shirts. Additionally, participants wore raincoats to increase their perspiration. To prevent any bacterial degradation, pads were collected immediately after each of the four sessions and deposited in dry ice. All donor samples were subdivided into 1 cm × 1 cm large pieces, samples of both anxiety sessions and samples of both exercise sessions were pooled and stored at −40 °C in big odorless freezer bags. Follow-up experiments were completed within the following 4 months (Lenochova, Roberts, & Havlicek, 2009). As a reference control condition, clean empty cotton pads were cut and stored using the same procedure as for the sweat samples.

On either day of the sweat samplings donors had to fill in the STAI X1 form multiple times. They had to complete the form once before the anxiety/exercise condition (t_0), during each of the two sweat samplings (t_1), and after either sweat sampling (t_2). To obtain the values during the sweat sampling, donors were told to fill in the form focusing on how they had felt during each assignment, respectively. Scores were averaged for the exercise condition over run 1 and run 2 and for the anxiety condition over parcour and pole.

2.3. Haegler's Risk Game

For repeated measures of participants' risk taking behavior under different conditions without a learning effect we invented a new computerized card game. Participants were told that they would see an unknown amount of play card pairs with values from 1 to 10, 1 being the smallest and 10 being the highest possible card. After seeing the first card (Fig. 1a), participants had to decide whether the second card (Fig. 1b), would be either higher or lower than the first card. If their choice was correct, participants gained reward points. If their choice was wrong, participants lost points.

Starting with 0 points, reward points were accumulated over the rounds, while it was also possible to accumulate a negative amount of points. Participants were instructed that reward points were valuable, and it was the goal of the game to accumulate as many points as possible. They were paid a fixed amount of money, which they were aware of before the study started, but there was no mapping between points and dollars. Nevertheless, participants were instructed to play HRG with the objective of winning as many points as they could. In total, 100 card pairs were pre-