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Social Situation Awareness: Empathic Accuracy in the Aircraft Cockpit

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Abstract

The present study assesses the innovative concept of empathic accuracy within a crew-aircraft-system in a realistic approach scenario. Empathy, one of the key skills of social situation awareness (SSA), was found to be altered in stressful situations. Challenging and surprising events lead to a decrease in empathic accuracy in both pilot flying and pilot monitoring. Stress therefore significantly impacts SSA and modifications in training, procedures and system design could help crews better manage their workload during surprising and challenging situations, leading to increased empathic accuracy and better crew interaction.

Keywords: situation awareness; social situation awareness; empathy; stress; control; socio-technical system

Introduction

The setting of a socio-technical system, such as an aircraft cockpit and its crew and environment, requires several competencies from the flight crew (International Civil Aviation Organization, 2013). Situation awareness (SA) (Endsley, 1995, Endsley, 2012) is one of these competencies. SA in aviation is defined as the recurrent and continuous perceiving, comprehending and projecting of the following components and states: (1) the aircraft and its systems, (2) spatial location of the aircraft, (3) time and fuel states, (4) possible threats to the safety of the aircraft, (5) development of what-if scenarios for contingencies, and (6) the awareness of people and their states involved in the operation including passengers (International Civil Aviation Organization, 2013). The last point is also called social situation awareness (SSA) or social cognition. As a myriad of cultural, organizational, human and technical

interrelationships are involved in a crew-aircraft system, being aware of the colleague's state within a cockpit is therefore of relevance. In order to have sufficient SSA, several social skills are required, one of which is empathy (Singer & Lamm, 2009, Singer & Tusche, 2014). Empathy is the ability to share the perceptual, emotional and cognitive states of the other (Singer & Lamm, 2009). Another crucial skill for gaining SSA next to empathy is communication competency. Both skills, empathy and communication, have an influence on the concept of shared mental models (SMM) (Burtscher & Manser, 2012, Evans, Harper, & Jentsch, 2004) which should be achieved so that a pilot can maintain SSA and be able to quickly adapt to the system, the task, and the colleague's demands. In aviation, there are examples where the combination of insufficient communication (Howard, 2008, Glavin, 2011, Molesworth & Estival, 2015), stress in various forms, e.g. social-evaluative threat (Andrews et al., 2007, Dickerson, Gable, Irwin, Aziz, & Kemeny, 2009, Denson, Creswell, & Granville-Smith, 2012, Hughes & Beer, 2013), and related human factors were found to have a significant influence on crew performance and were contributing factors in fatal incidents and accidents. Some examples are the following: mid-air collision above Zagreb (1976), Tenerife disaster (1977), Air Florida Flight 90 (1982), Avianca Flight 52 (1990), One-Two-Go-Airlines 269 (2007), Aeroflot 211 (2008), and Asiana Airlines 214 (2013). Evidence for the large impact of social aspects combined with stress comes not only from Accident Investigation Authorities but also from findings from prior research in laboratory settings that has shown that stress can influence social cognition (Tomova, 2014, Smeets 2009). However, there is still a gap

of knowledge regarding how stress and social skills such as empathic accuracy impact each other in highly trained socio-technical environments such as a crew-aircraft system and whether stress lowers empathic accuracy in well trained crews as it has been shown to in the general population in laboratory settings (*ibid.*). Thus, a flight simulator study was carried out and the following hypothesis was tested: SSA with a focus on empathic accuracy in highly trained aircraft crew is decreased for both pilots during stressful events.

Definition of Terms

Stress

Stress represents the response of an organism when a demand exceeds the regulatory capacities (Dickerson & Kemeny, 2004). In general, stress is known to trigger adaptive responses in two bodily systems: the fast-reacting sympathetic adrenomedullary system (SAM-system), and the slower hypothalamus pituitary adrenal axis (HPA-axis), both of which originate in the hypothalamus. Stress effects are particularly prevalent in attention (e.g., Vedhara, Hyde, Gilchrist, Tytherleigh, & Plummer, 2000, Elling et al., 2011), memory (e.g., Vedhara et al., 2000, Wolf, 2009), and decision making (e.g., Starcke & Brand, 2012). Furthermore, there is evidence that social cognition is altered under stress (Smeets, Dziobek, & Wolf, 2009, Tomova, von Dawans, Heinrichs, Silani, & Lamm, 2014). Thus, stress exhibits a strong impact on individual cognitive and affective functions which influence our team skills and may therefore influence our social interactions and relationships. In a meta-analysis performed by Dickerson and Kemeny (2004), uncontrollability and social-evaluative threat were determined as the core components of stress (Dickerson and Kemeny 2004). Especially in critical situations during a flight, where the system is not reacting in a way that the crew expects it to react, the experience of uncontrollability is very likely to occur. Thus, surprising and unpredictable responses of the aircraft might very likely induce feelings of uncontrollability in pilots which then might trigger a stress response. Additionally, not being able to control the airplane in a way the crew is expected to might lead to feelings of insufficiency which then might induce the fear of being judged negatively by other members of the cockpit crew. Thus, social evaluative threat might represent a contributing component to the stress response in surprising situations acting as a reinforcing factor together with feelings of uncontrollability. Therefore, critical situations during a flight might in fact trigger both core components of stress as defined by Dickerson and Kemeny. The impact this has on the crew's abilities to control an aircraft represents an important issue in the analysis of SA.

Empathy

Empathy – especially its cognitive processes such as perspective taking – represents a basic requirement for SSA and SMM. Empathy describes the isomorphic sharing and, ultimately, understanding of the emotional state of another person, but with full awareness that the source of the shared

feelings is the other person. Empathy can result from directly perceiving, imagining or inferring the emotions of others (Singer & Lamm, 2009). As such it represents a basic cornerstone of successful human interaction. It enables us to have a vivid and rich representation of the cognitive and emotional states of others, helping us to understand them and therefore enabling a smoother social interaction. In this understanding, empathy represents a multi-faceted construct which includes different key components, such as perspective taking, mimicry, emotional contagion, self-other distinction, and the flexible use of executive functions to trigger and regulate vicarious responses (e.g., Singer & Lamm, 2009, Lamm, Meltzoff, & Decety, 2010). Recent evidence from social neuroscience indicates that empathic responses are initiated by an interplay of two core components, which are bottom-up and top-down processes (e.g., Lamm et al., 2010, Fan, Duncan, de Greck, & Northoff, 2011). The first component is comprised of low-level, sensory-driven (“bottom-up”) and mostly automatic affective and perceptual responses. Key processes related to this component are emotion contagion and mimicry, which enable the individual to automatically match the affective and motor states of others without conscious deliberation (Singer & Lamm, 2009). While this component was the center of attention in early neuroscientific empathy research (for a review, see Preston & De Waal, 2002) accumulating evidence suggests that the experience of empathy not only relies on these affective mirroring components, but rather seems to be a flexible phenomenon that can be modulated and regulated by motivational, situational and dispositional factors (e.g., Lamm, Meltzoff et al. 2010). Therefore, the second core component which is intrinsically intertwined with the lower-level component is comprised of high-level (“top-down”) controlled cognitive and evaluative processes – such as perspective taking, cognitive control, and emotion regulation.

Methods

Experimental Settings & Procedure

Simulator Environments

The experiments were carried out in research simulators (AVES, GRACE), which reproduced realistic Airbus 320 (A320) and Boeing 747 (B747) environments. The advantage of such research simulators is the possibility to adapt the cockpit according to the research requirements.

A simulator briefing was carried out to describe the safety aspects of the simulator as well as to introduce the functional limitations and differences that the simulator has in comparison to a full-flight training simulator and to the real aircraft.

Procedure

Ahead of the start of the experiment, a familiarization scenario was flown to allow familiarization with the operation, environment, control response and motion of the simulator. Each crew member was asked to fly a manual approach to landing. The manual landing included an

instrument landing system (ILS) intercept. Thereafter each pilot flew steep turns to get used to possible differences in the stick forces of the pitch axis and control law dynamics. Finally, each crew member received a short introduction to the differences in flight plan handling using the Master Control Display Unit (MCDU).

After the familiarization with the simulator, an operational briefing was held in the briefing room which was carried out like a real airline briefing. The briefing materials the crew received for the operational briefing included weather forecasts for the destination and alternate airports in the form of Aircraft Communications Addressing and Reporting System (ACARS) printouts. Additionally, two iPads were handed out to the crew with Jeppesen Mobile FliteDeck for electronic charts and the Quick Reference Handbook (QRH) as a text document. Furthermore, the pilots were informed regarding the starting point of the simulation and of the flight plan, the fuel calculations and about system limitations. Finally, the crews were asked to behave like they do in actual flights and were not allowed to communicate with the instructor /observer on the jump seat.

Experimental Scenario

The experimental scenario was subdivided into five flight phases (initial approach [INI], instrument landing approach [ILS], go-around [GA], bird strike [BIRD], and final approach and landing [LAND]). It was based on a regularly scheduled flight from a European departure to destination airport. The start of the simulation was initiated approximately 15 to 20 minutes away from the destination airport.

The scenario was designed to include variability in workload, ambiguous, surprising as well as challenging situations and also forced a manual take-over of the aircraft. The challenging and surprising events were weather conditions at minimum height that required a go-around, a heading failure, wind-change and bird strike.

Participants

We conducted the experiments with full airline crews. All crews consisted of a captain and a first officer of the same airline, as far as possible. In total 20 crews volunteered. However, for the analysis we had to exclude one A320 crew because of a simulation error and one B747 crew due to a different type rating of the FO. Thus, we evaluated 18 crews (36 pilots), namely seven A320 crews (14 pilots [7 captains, 7 first officers]) and eleven B747 crews (22 pilots [12 captains, 10 first officers]). Of the 36 pilots participating 31 (2 female, 29 male) agreed to fill out a demographic questionnaire. All other questionnaires were filled out by all 18 crews (36 pilots) evaluated, unless mentioned otherwise. The pilots' average age was 43 years (SD = 10.4) with an average flying experience of 2,405.50 hours (SD = 1,886.61).

Both crew members held a current type rating at the time of the experiments for the aircraft to be simulated. The roles

of pilot flying (PF) or pilot monitoring (PM) during the experimental scenario were assigned by the crew themselves.

Measurements

Given the hypothesis, scenario and testing environment, we used several kinds of measures. These included methods that are already well established in aviation research, such as expert observations, de-brief interviews and questionnaires like the NASA TLX and SART. Additionally, we performed a behavioral content analysis from video observation and applied new approaches such as the SSA-VAS questionnaire. Due to space limitations, in this paper we will mainly focus on our analysis of empathic accuracy in the aircraft cockpit using the SSA-VAS.

SSA-VAS Questionnaire

After completion of the scenario, each participant filled out the newly developed SSA-VAS questionnaire. The SSA-VAS was used to evaluate how each crew member perceived their own stress and control of the situation as well as how each crew member perceived their colleague's stress and control of the situation. In order to avoid misunderstanding, the participants were informed that being in control does not derive from being the PF or PM but rather from confidently understanding the current situation, knowing what one is doing, knowing what the team member is doing, and knowing what upcoming actions will follow in regard to oneself and the team member.

The SSA-VAS questionnaire has two extreme poles, like the NASA TLX (Hart & Staveland, 2005, Hart, 2006) and SART (Taylor, 1990), ranging from 0 (cm; low) to 10 (cm; high) and is presented as a visual analog scale. Such a measurement instrument is applied for values that cannot be easily measured directly (Crichton, 2001). The questionnaire consists of four questions which in this case were related and referred to each flight phase separately. The questions in their basic form are the following:

1. How much were you in control of the situation?
2. How much was your colleague in control of the situation?
3. How stressed did you feel in the situation?
4. How stressed did your colleague feel in the situation?

Empathic Accuracy

Empathic accuracy was measured by comparing the control and stress ratings during each flight phase that each pilot gave to themselves (i.e., How much were you in control of the situation? / How stressed did you feel in the situation?) versus the ratings their colleague gave them (i.e., How much was your colleague in control of the situation? / How stressed did your colleague feel in the situation?) (see Equation 1 and Equation 2 below— examples are given for calculations of empathic accuracy of PF). This enabled us to have a direct measure of empathic accuracy of both pilots, i.e., PF and PM. This method represents an adapted version

of the empathic accuracy paradigm by Ickes et al. (Ickes, 1993).

$$EA_C = 10 - |PF_R \text{Control-Other} - PM_R \text{Control-Self}|$$

Equation 1: Calculation of empathic accuracy (EA) for control. Example for calculation of EA_C for PF.

$$EA_S = 10 - |PF_R \text{Stress-Other} - PM_R \text{Stress-Self}|$$

Equation 2: Calculation of empathic accuracy (EA) for stress. Example for calculation of EA_S for PF.

Results

A mixed model analysis of variance (ANOVA) with the within-subject factors flight phase (INI, ILS, GA, BIRD and LAND) and rating (self vs. other) and the between-subject factor role (PF vs. PM) was implemented for perceived stress and control. We implemented the same method to evaluate empathic accuracy however using the within-subject factors flight phase (INI, ILS, GA, BIRD and LAND) and type of assessment (control vs. stress) and the between-subject factor role (PF vs. PM).

Perceived Stress

We found a significant main effect of flight phase ($F(3.24,110.09) = 20.498, p < .001$) and a significant interaction of phase, rating and role ($F(1.55,52.56) = 5.473, p = .012$).

For a closer investigation of the main effect of flight phase, we computed Bonferroni corrected post-hoc comparisons of the stress ratings (mean across both roles and both ratings). The post-hoc comparisons showed a significant difference between flight phase INI and GA, BIRD and LAND (all p -values $\leq .001$) as well as flight phase ILS and GA, BIRD and LAND (all p -values $< .001$) while INI and ILS were not significantly different from each other ($p > .999$). Ratings for GA, BIRD and LAND were also not significantly different from each other (all p -values $> .100$). Thus, ratings show that GA, BIRD and LAND were rated as more stressful than INI and ILS (see Figure 1, Figure 2).

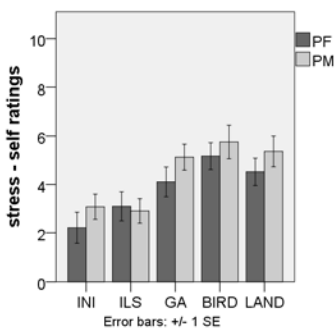


Figure 1: Mean ratings of stress for each flight phase – self ratings.

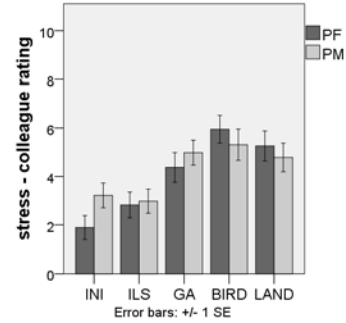


Figure 2: Mean ratings of stress for each flight phase – colleague ratings.

Perceived Control

There was a significant main effect of flight phase ($F(2.83,96.35) = 7.478, p < .001$) and a trend significant effect of rating ($F(1,36) = 3.784, p = .061$). We did not find a significant main effect of role or any interactions of role with other factors (all p -values $> .08$).

Again we computed Bonferroni corrected post-hoc comparisons of the control ratings for each phase (mean across both pilots and both ratings), for a closer investigation of the main effect of flight phase. The post-hoc comparisons showed a significant difference between flight phase INI and BIRD ($p = .029$) as well as flight phase ILS and GA ($p = .002$), BIRD ($p < .001$) and LAND ($p = .010$) while INI and ILS were not significantly different from each other ($p > .999$). Ratings for GA were not significantly different from INI, BIRD and LAND (all p -values $> .47$) but ratings for BIRD and LAND differed significantly ($p = .031$) (see Figure 3, Figure 4).

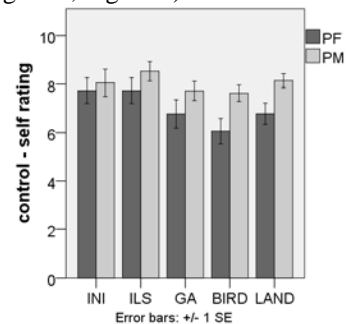


Figure 3: Mean values for perceived control of the situation for each flight phase – self ratings.

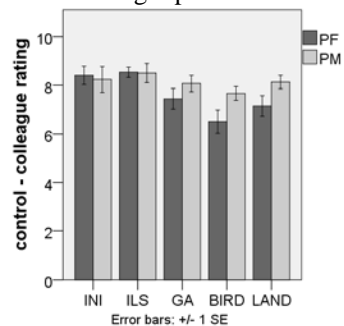


Figure 4: Mean values for perceived control of the situation for each flight phase – colleague ratings.

Empathic Accuracy

Due to the missing of one rating, the N for this analysis was 34 instead of 36.

We found significant main effects of flight phase ($F(2.91,93.07) = 4.341, p = .007$) and assessment ($F(1,32) = 7.724, p = .009$). Role and its interactions were not significant (all p-values > .36).

For a closer investigation of the main effects of flight phase and assessment, we computed Bonferroni corrected post-hoc comparisons of empathic accuracy for each flight phase (mean across both roles) for both assessments separately. For control assessments, the post-hoc comparisons showed a significant difference between flight phase INI and BIRD ($p = .049$) with higher empathic accuracy during INI (mean difference \pm SD = $.941 \pm .311$). For stress assessments, the post-hoc comparisons showed a significant difference between flight phase ILS and GA ($p = .002$) with higher empathic accuracy during ILS (mean difference \pm SD = $1.406 \pm .329$) (see Figure 5, Figure 6).

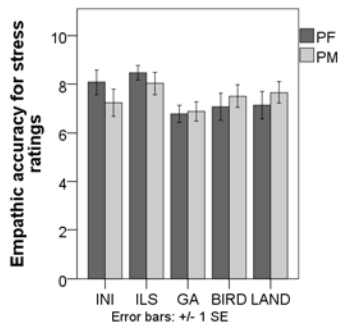


Figure 5: Empathic accuracy for the assessment of stress for each flight phase.

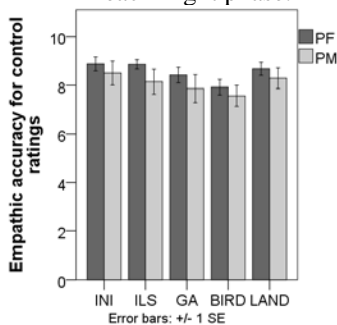


Figure 6: Empathic accuracy for the assessment of control for each flight phase.

Discussion

We found an effect of flight phase on the stress and control ratings of pilots, both on self-ratings and on the ratings pilots assigned to their colleagues. We can conclude from these ratings that the flight phases GA, BIRD, and LAND were most stressful for the pilots. Thus, there is evidence that the experimental scenario triggered the intended effects and that crews were immersed into their tasks. Furthermore, we found a significant effect of flight phase, on the empathic accuracy of pilots. Based on self-ratings of stressfulness of each flight phase, we were able to

determine which flight phases were stressful and thus compare empathic accuracy between stressful and non-stressful flight phases. More specifically, empathic accuracy was lowest during the stressful flight events BIRD (for control ratings) and GA (for stress ratings). This effect was present for both crew members, the PF and PM. This implies that crews were uncertain regarding their colleague's stress level. Under less stressful conditions, pilots were better able to accurately assess the state their colleague is in. When stress levels were higher, pilots' empathic accuracy decreased and they were less able to judge how stressful their colleagues perceived the situation to be. This is likely exacerbated by the fact that flight crews do not usually work in fixed pairings, decreasing the time individual pilots fly with one another, and the fact that surprising and challenging situations are rare due to good trainings and reliable systems. To increase pilots' empathic accuracy regarding stress, it may be useful to have crews fly together more often.

The BIRD phase of the scenario was the most stressful according to the self-ratings. During this flight phase pilots had the worst empathic accuracy regarding their colleagues' perceived level of control. When pilots cannot accurately judge how much control their colleagues feel, competencies such as leadership, communication, decision making, monitoring, and SA can be negatively impacted. As a result, pilots may be less able to sufficiently guide their colleagues through challenging situations, carry out effective communication, and make adequate decisions. In order to increase pilots' empathic accuracy regarding perceived level of control, trainings, procedures, and system design could be modified to support crews even better in surprising and challenging situations.

Taken together, in the present SSA-VAS analysis, we were able to confirm the hypothesis that stress, i.e., challenging and surprising situations during flight, leads to altered social cognition. We found that empathic accuracy between pilots was decreased during stressful situations in a challenging approach scenario.

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