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Anticipatorily Controlled Top-Down Processes Influence the Impact of Coriolis Effects

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The impact of the vestibular-induced Coriolis illusion becomes apparent in spatial disorientation and symptoms of motion sickness. Empirical data indicated that anticipatory processes, evolved by experience, influence the sensation of Coriolis illusion. We measured subjective well-being and stress responses of 13 experienced pilots and 13 non-pilots in order to study the influence of anticipatorily controlled top-down attention on the impact of Coriolis effects and to examine the role of experience. Subjective data and psychophysiological data (EDA, ECG) were recorded, reflecting the underlying psychological processes involved. Participants distracted by doing a reaction test (experimental group) gave higher drowsiness ratings and higher dizziness ratings than non-distracted participants (control group) immediately after the Coriolis induction, independently of experience. EDA data showed higher emotional stress responses in the experimental group throughout the psychophysiological sensation unit of 4x10s. Data suggest that anticipatorily controlled top-down processes are of particular importance in Coriolis-provoking environments.

Coriolis illusion is known for its incapacitating effects on a pilot's spatial orientation and/or physical well-being (e.g. dizziness, drowsiness), and hence, pose high safety risks in aviation (Gibb, Ercoline, & Scharff, 2011). Empirical data revealed that anticipatory top-down processes, evolved by experience, attenuate the impact of the Coriolis illusion (Talker, Kallus, Schwandtner, Joachimbauer, & Beykirch, 2014) and can improve a pilot's performance in disorientation-prone flight situations (Koglbauer, Kallus, Braunstingl, & Boucsein, 2011; Tropper, Kallus, & Boucsein, 2009). Gresty, Golding, Le, & Nightingale (2008) emphasized that attentional processes are of vital importance to regain orientation when spatial orientation is threatened. As top-down attention is mostly controlled anticipatorily (Butz & Pezzulo, 2008), the question arises whether the distraction of anticipatorily controlled attention influences the impact of the Coriolis illusion.

In flight, a pilot's awareness of her/his position and the attitude of the aircraft in relation to the gravitational vertical is pivotal for flight safety. A pilot's spatial orientation is threatened by different kinds of sensory illusions. One of the most dangerous vestibular-induced illusions is the Coriolis illusion (Cheung, 2013). Coriolis illusion can emerge from special flight maneuvers, as well as during prolonged turns when the pilot moves the head out of the axis of rotation. Moreover, the Coriolis illusion can provoke symptoms of motion sickness (MS). These evoked effects can severely impair the performance of those affected (Benson, 2002). The most influential theory explaining the occurrence of motion sickness is the Sensory Rearrangement

Theory (Reason & Brand, 1975). The authors emphasized the particular importance of experience by postulating a mismatch of the perceived sensory information with what is expected from previous experience. This proposed expectation process may arise from a mental model which may be generated and "updated" by a continuous anticipation-action-comparison learning process (Hoffmann, 1993; Kallus, 2012). This ongoing match-mismatch comparison of actually sensed multi-sensory information (visual, vestibular and proprioceptive cues) and anticipated multi-sensory patterns memorized from previous experience might lead to the formation of correct anticipations of upcoming (flight) situations. Distracting top-down attention from ongoing (flight) situations might influence anticipatory processes, and hence, the sensation of Coriolis effects. In order to shed light on this issue, we investigated the impact of Coriolis effects in dependence of distraction and examined the role of experience. Well-being and stress responses were investigated by collecting subjective data (ratings, questionnaires and reconstruction interviews) and psychophysiological data (EDA and ECG).

Method

Participants

13 active pilots and 13 non-pilots participated in the study, including two females, each. Pilots were between 20 and 55 years old (M = 41.08, SD = 10.40); non-pilots between 19 and 65 years, M = 34.46, SD = 12.69. The difference, $T(1,24) = 1.453$, $p = .159$ (*n.s.*), did not reach significance. Among the pilots, there were VFR pilots and IFR pilots. The pilots' flight experience ranged from 60 to 2.000 flight hrs; their experience with flight simulators ranged from "no experience" to 50 hrs. The participants in the sample of non-pilots were required not to have any experience in operating an aircraft and to have no or low experience with flight simulators. All participants took part in the experiment voluntarily. They signed an informed consent and were informed that they could quit the experiment whenever they wished, without giving any reasons. Each participant received an expense allowance of 75 Euro at the end of the experiment.

Design and Procedure

Participants were assigned to two groups according to their experience in flight motion (pilots vs. non-pilots). The main part of the experiment was comprised of the evaluation of Coriolis sensations. In the scenario of interest, Coriolis illusion was induced passively, i.e. solely by motion of the simulator cabin. The scenario consisted of a pitch-up motion of the cabin in CAVOK (*Ceiling And Visibility OKay*) weather conditions. The simulator cabin constantly rotated clockwise. The condition of the experimental group included an imperative stimulus indicating the beginning of the testing phase followed by a reaction test. Participants had to push a button once they had heard a particular sound sequence via the headset. The end of the testing phase was indicated by a second stimulus after the Coriolis induction. There was no sound sequence during the Coriolis induction. The control group received two control stimuli indicating the beginning and the end of the testing phase. The investigation took place at the premises of AMST-Systemtechnik GmbH in Ranshofen, Austria, using the AMST motion flight simulator AIRFOX®ASD. The simulator session of the passive maneuvers required approximately 25 minutes in total. At the beginning, participants received detailed information about the procedure. Immediately after each maneuver, participants evaluated their subjective well-being via headset. After the simulator session, a reconstruction interview was conducted in order to figure out special aspects of Coriolis sensations.

Dependent Variables

Since the main purpose of this paper is to report the data of the passive scenario with distraction, only the key dependent variables of the multilevel approach will be mentioned. As a key symptom of spatial disorientation, participants evaluated the degree of dizziness on a scale from "0" (no dizziness) to "20" (extremely strong dizziness) (adapted from Keshavarz & Hecht, 2011) and drowsiness as a key symptom of MS ("0" = no drowsiness to "20" = extremely strong drowsiness) after each Coriolis maneuver. After the simulator session, participants were interviewed in regard to their sensations and mental pictures during the Coriolis maneuvers by using a post-task reconstruction interview.

During the entire simulator sequence, electrodermal activity (EDA) was recorded with the Varioport Biosignalrecorder (Becker Meditec, Karlsruhe, 2005). The received signal was monitored on an additional Laptop screen using the software Variograf Win32: Rev. 4.76 © G. Mutz 1988 – 2005 (Dipl.-Ing. Becker Meditec; 2005). Baseline measurements of 60 seconds were collected. The recording of the EDA was done using two active (0.5 Volt) non-polarised silver/silver chloride electrodes with a diameter of 22 mm (1 cm^2 measurement area). Signals were recorded from the plantar recording sites of the non-dominant foot as described by Boucsein (1992). Before application, the electrodes were filled with 0.5% non-ionising NaCl paste. The resulting conductance was measured with a resolution of 0.002 µS. The parameters SCL (skin conductance level) and NS.SCRfreq (frequency of non-specific skin conductance responses) were evaluated using the program EDA-Vario, Version 1.94 (Schaefer, 2009).

Statistical Analyses

Statistical evaluation was performed with SPSS 22.0. Subjective data were analyzed using the procedure of a two-factorial ANOVA. Psychophysiological data were evaluated by means of a multivariate analysis of variance (MANOVA) for repeated measurements. A significance level of $\alpha \leq .05$ was adopted for the statistical tests. The assumption of normal distribution was checked by means of the Kolmogorov-Smirnov Test, the premise of variance homogeneity was evaluated by means of Levene Test, and the sphericity assumption was evaluated by means of the Mauchly's Test. Repeated measures effects were based for all variables on the Huynh-Feldt Tests, using corrected degrees of freedom for countering the exceptions from the homogeneity assumption. Due to the explorative character, no correction for type-I-error was conducted. For the EDA parameters (SCL, NS.SCRfreq), baseline corrections were computed. Statistical analyses of EDA parameters were based on 10-second intervals of analyses where time intervals of 4x10 seconds were combined to a psychophysiological unit.

Results

The goal of this experimental scenario was to investigate the impact of Coriolis effects in dependence of distraction and to examine the influence of experience. A two-factorial ANOVA was conducted with *Distraction* and *Experience* as independent variables and *Drowsiness* as dependent variable. The results revealed a significant between-subject main effect for *Distraction*, $F(1, 20) = 4.992$, $p = .037$, $\eta_p^2 = .200$. Participants who received the imperative stimulus (and did the reaction test) gave higher drowsiness ratings as compared to the control group, immediately after the Coriolis induction. The between-subject main effect for *Experience*, $F(1, 20) = .186$, $p = .671$, $\eta_p^2 = .009$, did not reach statistical significance. There was no significant interactive effect between *Distraction* and *Experience*, $F(1, 20) = .282$, $p = .271$, $\eta_p^2 = .060$. Results of the dizziness ratings revealed higher dizziness ratings of the experimental group as compared to the control group. The between-subject main effect for *Distraction*, $F(1, 20) = 2.522$, $p = .128$, $\eta_p^2 = .112$, and the between-subject main effect for *Experience*, $F(1, 20) = 1.282$, $p = .271$, $\eta_p^2 = .060$, did not reach statistical significance. There was no significant interactive effect between *Distraction* and *Experience*, $F(1, 20) = .634$, $p = .435$, $\eta_p^2 = .031$. However, it has to be noted that, after the simulator session, experienced pilots reported significantly less physical discomfort (e.g. nausea, vertigo), $T = -2.06$, $p = .028$ *(1-tailed sig.)*, due to Coriolis induction as compared to non-pilots (Talker et al., 2014).

The baseline-corrected EDA parameters (mean NS.SCRfreq, mean SCL) were analyzed in time intervals of 10 seconds with the four different time intervals as levels of the within-subject factor *Psychophysiological Unit* (Reference, Anticipation/Reaction Test, Coriolis Sensation, Post-Coriolis Sensation), and the two categories of distraction of attention (imperative stimulus vs. control stimulus) as levels of the between-subject factor *Distraction*. A repeated measures multivariate analysis of variance (MANOVA) was conducted with *Psychophysiological Unit* and *Distraction* as independent variables and NS.SCRfreq and SCL as dependent variables. The results revealed a non-significant between-subject main effect for *Distraction*, *Wilks'* $\lambda = .788$, $F(2, 19) = 2.556$, $p = .104$, $\eta_p^2 = .212$, and a highly significant within-subject main effect for *Psychophysiological Unit*, *Wilks'* $\lambda = .157$, $F(6, 15) = 13.392$, $p < .001$, $\eta_p^2 = .843$. There was no significant interactive effect between *Distraction* and *Psychophysiological Unit*, *Wilks'* $\lambda = .722$, $F(6, 15) = .962$, $p = .482$, $\eta_p^2 = .278$.

Based on the responses of the experimental group in the reconstruction interview, psychophysiological data were analyzed in dependence of allocation of attention. A repeated measures multivariate analysis of variance (MANOVA) was conducted with *Psychophysiological Unit* and *Allocation of Attention* as independent variables and NS.SCRfreq and SCL as dependent variables. Results revealed a significant between-subject main effect for *Allocation of Attention*, *Wilks'* $\lambda = .408$, $F(2, 9) = 6.537$, $p = .018$, $\eta_p^2 = .592$. Participants who allocated their attention to the ongoing flight scenario showed less electrodermal responses as compared to participants who allocated their attention to the distracting stimulus. There was a significant within-subject main effect for *Psychophysiological Unit*, *Wilks'* $\lambda = .130$, $F(6, 5) = 5.584$, $p = .039$, $\eta_p^2 = .870$. The interactive effect between *Distraction* and *Psychophysiological Unit*, *Wilks'* $\lambda = .743$, $F(6, 5) = .288$, $p = .919$, $\eta_p^2 = .257$, did not reach statistical significance.

To sum up, participants distracted with the imperative stimulus (experimental group) reported significantly higher drowsiness ratings and higher dizziness ratings immediately after the Coriolis induction than participants distracted with the control stimulus (control group), independently of experience. Psychophysiological data (NS.SCRfreq, SCL) recorded during the simulator session revealed a higher electrodermal activity of the experimental group throughout a

Psychophysiological Unit (i.e. before, during and after the Coriolis induction) as compared to the control group. The analyses of electrodermal responses of the experimental group in dependence of *Allocation of Attention* (scenario vs stimulus) showed significantly less mismatch responses in participants who mainly allocated their attention to the scenario before, during and after the Coriolis induction.

Discussion and Conclusions

In this experiment, we shed light on the role of anticipatorily controlled top-down processes on the sensation of Coriolis illusion and examined the influence of experience. Subjective data revealed that distracting top-down attention by a reaction test led to a higher impact of Coriolis effects, independently of experience. These results extend the findings of Talker et al. (2014) that revealed less impairment of experienced pilots' subjective well-being after a Coriolis session in the flight simulator as compared to non-pilots. While the results of Talker et al. are well in line with the Sensory Rearrangement Theory (Reason & Brand, 1975), the results at hand indicate that top-down attention might be an important influencing factor.

EDA data recorded during the simulator session supported the subjective rating of well-being. The effects on EDA parameters are well in line with modern arousal conceptions like the 4-arousal-model (Boucsein & Backs, 2009). Higher levels of electrodermal responses throughout the Psychophysiological Unit of 4x10 seconds indicated that participants of the experimental group experienced more negatively toned emotions and/or emotional stress in the Coriolis-prone environment as compared to the control group. It can be interpreted that the distraction of attention might have influenced anticipatory processes negatively, so that the expectation of upcoming sensory information matched the actual sensed sensory information to a lower degree and, hence, led to a higher impact of Coriolis effects. Interestingly, participants of the experimental group showed significantly less mismatches when they allocated their attention mainly to the ongoing scenario. In this experiment, the results of subjective data and psychophysiological data suggest that anticipatorily controlled top-down processes are of particular importance in Coriolis-provoking environments.

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