Analyzing Pilot Experience of Flying in Formation through the Course-of-Action Framework: A Case Study of Helicopter Pilot Trainee

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ABSTRACT

This case study investigated the experience of a military helicopter pilot trainee during formation flight. Formation flight is a technique used in military operations, consisting of maneuvering safely around a Lead helicopter by controlling the rate and direction of motion to avoid collisions. Using the Course-of-Action framework, we described the pilot's cognitive activity during formation-flight maneuvers (join-up patterns) in a practice session from his own perspective to provide insights into his lived experience. Focus was placed on the situational elements that were meaningful to the pilot at a given moment (i.e., Representamen), and how these meaningful situational elements were guided by his situated concerns (i.e., Involvement). Data were collected in two steps: (1) collection of activity traces during formation flight training and (2) self-confrontation interviews using these activity traces in which the pilot was invited to relive his experience and describe his activity. The results indicated five typical representamen and four typical involvements, and revealed eight different associations between these typical representamen and typical involvements over the course of the maneuvers. The discussion addresses how the description of these associations provides a better understanding of the pilot's activity during formation maneuvers and proposes possible extensions of this study.

CCS CONCEPTS

• **Human-centered computing** → Human computer interaction (HCI); Empirical studies in HCI; • **Applied computing** → Law, social and behavioral sciences; Psychology.

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ECCE 2024, October 08–11, 2024, Paris, France

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ACM ISBN 979-8-4007-1824-3/24/10
https://doi.org/10.1145/3673805.3673850

KEYWORDS

Helicopter pilot training, Formation flight, Course-of-Action, Self-confrontation interview

ACM Reference Format:
Damien, Morisson, Régis, Lobjois, Barthélémy, Minier, Franck, Mars, and Sami, Mecheri. 2024. Analyzing Pilot Experience of Flying in Formation through the Course-of-Action Framework: A Case Study of Helicopter Pilot Trainee. In *European Conference on Cognitive Ergonomics (ECCE 2024), October 08–11, 2024, Paris, France.* ACM, New York, NY, USA, 4 pages. https://doi.org/10.1145/3673805.3673850

1 INTRODUCTION

Formation flight is a technique used for tactical reasons in military operations, where a Wing helicopter flies with a Lead helicopter (first aircraft in the formation, responsible for leading the flight). The Wing pilot must carefully control the direction and rate of relative motion to maintain a constant and safe separation from the Lead while executing formation maneuvers. During maneuvers, the Wing's position relative to the Lead is prescribed in terms of step-up (vertical separation between Lead and Wing), bearing (Wing's position relative to Lead in the horizontal plane), and distance, particularly as distance decreases to avoid trajectories that may converge on the Lead and potentially cause collisions [1]. In what follows, we present the preliminary findings of a case study aimed at describing the Wing pilot's cognitive activity during formation-flight maneuvers from his own viewpoint.

While the cognitive activity of pilots is typically investigated using performance, neurophysiological and eye-tracking measures [2], thereby examining pilot-environment interactions "from the outside" (experimenter's perspective), this study was conducted within the course-of-action framework [3], which is effective for providing insights into the activity "from the inside". Originating in ergonomics and rooted in the enactive approach, this program defines human activity as enacted, lived, situated, embodied, and enculturated [4]. It focuses on the actor's lived experience to access to his meaningful activity. Lived experience is here reduced to the part of consciousness that accompanies situations without implying any reflective act on this experience [4]. This part of consciousness is called pre-reflexive consciousness and is accessed through the part of the human activity that can be told, shown or commented by an actor at any moment. A self-confrontation interview is conducted to enable an actor to re-enact his past experience, by confronting him with traces of his activity, allowing the researcher to question the actor about his/her lived experience [4]. This framework has proven its fruitfulness in analyzing performer-environment interactions in other dynamic, time-constrained tasks in high-performance [5] and learning [6] contexts. Such studies provided an in-depth understanding of the way performers organize their activity and revealed how learners make sense of their performance environment.

Using this framework, the purpose of this case study was to explore the experience of a military helicopter trainee during a formation-flight practice session conducted in a high-fidelity simulator. A focus was made on the situational elements that were meaningful from his own viewpoint (i.e., Representamen) and his concerns (i.e., Involvement) over the course of the maneuvers. This allowed for an analysis, conducted step-by-step, of the experiential contents related to the situational elements that were meaningful to the pilot at a given moment, and how these meaningful situational elements were guided by his situated involvements.

2 METHOD

2.1 Task and Participants

The study was conducted in collaboration with a military flight school. The pilot who volunteered to participate was a helicopter pilot trainee undergoing initial formation-flight training. The practice session was carried out in the flight simulator used for instruction and was scheduled after the participant received classroom instruction and three simulator training sessions with an instructor. The pilot had to perform, in the absence of the instructor, two Join-Up (JU) maneuvers when the Lead was in a turn. JU had three steps: 1) join on by flying in the Lead's direction, aiming forward of the Lead's current position at a higher speed inside his turn, 2) slow down when approaching until cancelling convergence ("*controlled convergence*"), 3) get closer to establish in close formation on the outside or inside of the Lead's turn at the correct distance (three rotor diameters) and correct bearing (45-degree bearing). The maneuvers were completed in around four minutes.

2.2 Data Collection

Two types of data were collected: 1) video data of the formation-flight practice session from camera glasses worn by the pilot, 2) verbalization data collected during self-confrontation interview that took place the same day and lasted 52 minutes. The self-confrontation interview consisted in confronting the pilot with the recorded video to make him "re-live" his activity. The researcher used prompts to guide the pilot in a chronological description of his re-lived experience, expressing as precisely as possible what he aimed for, did, expected, felt, thought, and perceived at every moment. The answers of the participant could then be the subject of requests for more details to obtain the most accurate description possible of his experience.

2.3 Data Processing

The data were processed in four steps. The first involved describing the actions and communications of the pilot and transcribing the interview. The second step involved constructing a two-part table showing the temporal correspondence between pilot's actions and communications and the interview transcript. The third step consisted of reconstructing hexadic signs at a given moment to describe the course-of-action [4], before focusing on articulating three components of the pilot's experience: involvement, representamen and referential (see Table 1). This allowed for the characterization of associations between involvement and representamen. The fourth step aimed to identify typical involvements and typical representamen using inductive-categorization principles, thereby enabling the analysis of associations between typical involvements and typical representamen (hereafter written [Typical Involvement / Typical Representamen]). Data were coded by two researchers who reached consensus on the labeling of the experiential components.

3 RESULTS

3.1 General Results

Four typical involvements were identified: "Manage the Risk of Convergence", "Not to Be Left Behind", "Get Closer to the Lead" and "Shift Relative to the Lead". Five typical representamen were identified: "Previous Training Events", "Capability of the Helicopter", "Expansion Rate of the Lead", "Positioning Cues" and "Relative Motion". The analysis revealed eight associations between these typical involvements and typical representamen (Figure 1). The specific situational elements, the specific concerns, as well as the pilot's knowledge elements that participated in the emergence of each association are described in the next section.

3.2 Associations between Typical Involvements and Typical Representamen

3.2.1 [Manage the Risk of Convergence / Previous Training Events]. Managing the risk of convergence consists of the pilot controlling his relative heading angle (and heading vector norm) with respect to the Lead, so that he can adjust his trajectory at any time to avoid a collision. The pilot was concerned with managing the risk of convergence while focusing on the memory of a previous training event where he joined on the Lead from the six o'clock position, after the Lead announced the maneuver but before he initiated the turn. In doing so, the pilot inadvertently reduced separation to an uncomfortable distance, making it difficult to control convergence for the rest of the maneuver. From this prior event, the pilot had knowledge that increasing speed from the six o'clock position, rather than during Lead's turn, makes it challenging to perceptually judge and master his approach. He thus mobilized this knowledge to avoid accelerating from this position and to safely manage the convergence risk while joining on the Lead.

3.2.2 [Manage the Risk of Convergence / Expansion Rate of the Lead]. The pilot was concerned with managing the risk of convergence while focusing on the expansion rate of the Lead. The pilot explained that the expansion rate conveys useful information about the speed at which his distance from the Lead was changing, and

Table 1: Reconstructed components of experience.

Component	Definition	Analytical Questions
Representamen	Situational elements that are meaningful for the pilot at a given moment	What are the significant elements of the situation for the pilot? What is the remembered, perceived or interpreted element that is significant for the pilot?
Involvement	Significant concerns of the pilot regarding the Representamen	What are the significant concerns of the pilot regarding the considered element in the situation?
Referential	Knowledge involved at a given moment related to the Representamen and the Involvement	What is the knowledge involved at that given moment?

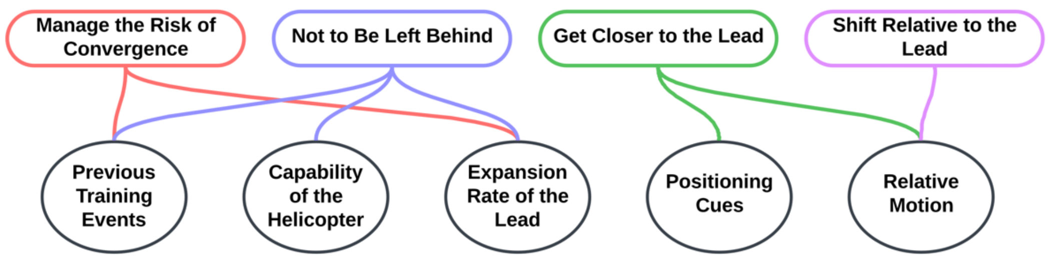

Figure 1: Associations between typical involvements (top) and typical representamen (bottom), for the JU maneuver.

that a high rate of expansion while converging places the formation in dangerous position. In some instances, the pilot monitored the expansion rate to detect the exact moment when it would be excessive. In doing so, he felt that he could "stop" at any time by making smooth trajectory corrections with small cyclic inputs aft and away from the Lead. In other instances, his focus on the expansion rate led to the rapid perception that the Lead was too large in the windscreen, necessitating a prompt correction for distance. The pilot thus took the expansion rate of the Lead into account when he aimed to exert tight control over convergence or to open distance from the Lead to master the risk of convergence.

3.2.3 [Not to Be Left Behind / Previous Training Events]. Not being left behind means avoiding moving away from the Lead due to a negative relative speed and/or a longer distance to fly. The pilot was concerned with not being left behind while focusing on the memory of a previous training event where he mismanaged the aircraft's energy and struggled to catch up. In this prior event, the pilot found himself in proximity to the Lead after gaining much step up, creating an excess of potential energy from his own viewpoint. He thus adjusted the aircraft's energy state by reducing power and slowing down to avoid overtaking the Lead. This led him to subsequently sink behind the Lead when he had to catch up from the position in which he remained, as he had more distance to fly outside of the Lead's turn. The pilot thus had knowledge of the consequences of a dissipating his energy at this moment of the maneuver. In this situation-specific context, the pilot thus focused on this prior training event and actualized his concern for striving to maintain separation after gaining step up.

3.2.4 [Not to Be Left Behind / Capability of the Helicopter]. The pilot was concerned with not being left behind while focusing on the capability of his helicopter. This occurred during moments when the pilot was flying close to the power limitation of his aircraft. In such circumstances, the pilot knows that an increase in separation distance would leave him unable to increase power, causing him to inevitably fall behind the Lead. While focusing on power limitation, the pilot actualized his involvement by accelerating slightly, thus reducing the eventuality where he could no longer accelerate while staying below the power limitation. The capability of the helicopter was thus taken into account to prevent opening too much distance from the Lead in a proactive manner, by scaling steering according to power limitation and projection of possible future situational states.

3.2.5 [Not to Be Left Behind / Expansion Rate of the Lead]. The pilot was concerned with avoiding being left behind while focusing on the expansion rate of the Lead. This occurred when the pilot perceived the constancy of the size of the Lead in the windscreen, giving him the feeling of "being stopped", as if he had ceased moving forward. He explained that he knew he had to end this situation by getting closer; otherwise, he would never join up with the Lead. He thus aimed to catch up, pulling in a little power and moving the cyclic forward to ensure the helicopter accelerated instead of climbing. This association also emerged when the pilot was monitoring how the Lead expanded in the windscreen with the aim of determining the moment at which convergence would be controlled. The pilot knows that judging his convergence as controlled too early would be detrimental, as he would then struggle to close distance during the final portion of the maneuver. The expansion rate of the Lead was thus considered by the pilot to judge when to enter the final portion of the maneuver or when to accelerate to prevent being left behind.

3.2.6 [Get Closer to the Lead / Positioning Cues]. Getting closer to the Lead consists of the pilot reducing separation until approaching three rotors distance and stabilizing on the 45-degree bearing. The pilot was concerned with getting closer to the Lead while focusing on visual positioning cues located on the Lead. During the approach, the pilot was concerned with first positioning at the correct longitudinal distance as quickly as possible. He explained that establishing at the correct longitudinal distance is more time-consuming than gaining the desired step up or the correct bearing by laterally getting closer. Crucially, the pilot knows that the correct longitudinal distance is recognized with a specific visual reference point: when the back of the near skid passes through the front of the far skid, thus lining up in his visual field. Approaching the correct distance, the pilot thus visually controlled his approach on the Lead's skids to make finer adjustments as the distance decreased, until skids overlapped.

3.2.7 [Get Closer to the Lead / Relative Motion]. The pilot was concerned with getting closer to the Lead while focusing on the relative motion, i.e., the movement between the two helicopters as referenced from each other. By focusing on relative motion, the pilot felt at a specific moment that his convergence was "controlled", a condition to be met before switching to the final portion of the maneuver. The perception of a "controlled convergence" affected the pilot's activity as he actualized his interest in the situation in order to switch flying procedures. The pilot knows that properly getting closer to the Lead until achieving close formation requires a drastic change in visual-behavior requirements, consisting of scanning different visual reference points on the Lead, one at time, rather than on Lead's as a whole. While perceiving a controlled convergence from relative motion, the pilot thus aimed to reconfigure his cognitive schema to the newly relevant procedure, in order to start relying on specific positioning cues for approaching.

3.2.8 [Shift Relative to the Lead / Relative Motion]. Shift relative to the Lead consists for the pilot of varying the bearing line. The pilot was concerned with shifting relative to the Lead while focusing on the relative motion. This occurred when the pilot observed how the Lead was sliding away from him in order to perceive the Lead's radius of turn. The pick-up of this information was concomitant with the pilot's interest in adopting a different bank angle (and thus a different radius) than the Lead. The pilot knows that a difference in turning radius reduces path length and allows returning to the 45-degree bearing without large collective adjustments. In another situation, the pilot focused on the Lead sliding away from him in order to judge the Lead's slide motion relative to the horizon, using this information to create a different turning radius during join up. The motion of the Lead sliding away thus emerged as significant for the pilot as he planned and calibrated his own turn to efficiently regain the bearing line.

4 DISCUSSION

The present study analyzed helicopter pilot trainee experience during formation-flight maneuvers, examining the situational elements that were meaningful to him at a given moment (i.e., Representamen) in relation to his situated concerns (i.e., Involvement). The analysis revealed a total of eight associations between typical representamen and typical involvements, stemming from specific relationships between five typical representamen and four typical involvements.

The results illustrate that pilot-environment interactions during JU maneuvers are structured by multiples sources of meaningful situational information from the pilot's viewpoint, corresponding to both perceptual (visual) information from the environment (*Expansion Rate of the Lead*, *Positioning Cues*, *Relative Motion*) and contextual (non-perceptual) information (*Previous Training Events*, *Capability of the Helicopter*). While the reliance on visual information for flying in formation is not surprising [1], our findings characterize the fluctuating interdependence between the pick-up of task-relevant visual information and the pilot involvement in the situation. Notably also, the pilot experienced contextual elements that organized his activity at specific moments, indicating that he was able to make use of contextual resources from the current situation to control his maneuvers. This highlights that his cognitive activity was shaped by context-specific situational elements in addition to visual information arising from the Lead.

This case study will be extended by a second interview with the same pilot after full formation-flight training. This would allow understanding the experiential changes resulting from the acquisition of skills underlying flying in formation. Furthermore, other pilots will be included to conduct qualitative comparisons of their course-of-actions in order to identify singularity and genericity from the associations between involvements and representamen. The outcome may be useful to instructors in gaining a better understanding of how trainee pilots organize their formation flying activity "from the inside".

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