P57 - Proactive eye-gaze for predicting repetitive worker behavior

Short paper

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Short paper: Abstract Proactive eye-gaze (PEG) is a behavioural pattern where eye fixations precede actions, such as reaching. With the proliferation of eye-tracking technology, PEG shows promise for predicting human actions, which has many applications, for example, within industrial human-robot collaboration (HRC). This study investigates PEG in repetitive assembly tasks. Eye-tracking data from four experienced workers were recorded and analysed. The study recorded 57 assembly sessions, identifying 3793 fixations, of which 35% were proactive gazes. The mean PEG interval was 795 ms. Contrary to the hypothesis, PEG was found to be as strong, if not stronger, in repetitive tasks compared to previous studies investigating PEG in other contexts. These findings suggest PEG could be a reliable predictor of worker actions in repetitive tasks, enhancing coordination in HRC.

Background Proactive eye-gaze (PEG) is a behavioural pattern where many types of human actions, including reaching actions, are preceded by eye-fixations on the target. The phenomenon has been studied extensively (e.g. Johansson et al., 2001; Land & Hayhoe, 2001; von Hofsten, 2004), revealing a PEG of several hundred milliseconds (Gredebäck & Falck-Ytter, 2015). As eye-tracking technology becomes increasingly ubiquitous, PEG could potentially constitute a powerful cue for predicting human action. Action prediction has a wide range of application areas, including industrial settings where prediction of worker behaviour could increase safety and improve interaction with automation technology, such as collaborative robots (Billing et al., 2019).

One of the main application areas for industrial human-robot collaboration (HRC) lies within assembly tasks that today are executed manually. Many assembly tasks within industries are very repetitive, where the same action may be executed in almost exactly the same way hundreds of times each day. One example is manual assembly of wire harnesses inside cars. Wire harness assembly is difficult to automate due to the flexible nature of cables and therefore performed manually by workers. However, these installations are also challenging for human workers, often comprising high load forces on arms and hands, resulting in wear and tear injuries. Along with the electrification of vehicles, both the number of cable assemblies and the involved load forces are expected to increase dramatically, making wire harness installations among the most common causes of ergonomic issues in car manufacturing.

If wire harness assemblies are to be executed collaboratively between human workers and robots in a way that is both efficient and safe, PEG could be a key component in implementing coordination mechanisms between human workers and robots. While PEG has been investigated in a range of tasks, including cooking (Hayhoe et al., 2003), sports (Land & McLeod, 2000), and driving (Land & Lee, 1994), less is known about PEG in highly repetitive tasks such as assembly. While assembly is similar to many everyday activities in that it comprises pick and place actions, it also differs in that the environment is much more predictable and that tasks are executed in a similar way, over and over again.

In the present work, we aim to assess the usefulness of PEG as a predictive queue for human worker actions in repetitive tasks, such as assembly. As a starting point, we ask to what extent PEG is present also in these repetitive tasks. We hypothesise that the predictable environment, in combination with the worker's extensive experience, could make forward looking redundant, leading to declining, or even disappearing, PEG.

Method Eye-gaze of four industry workers (age 23-43) at Volvo Cars (Torslanda, Sweden) were recorded during manual assembly operations as part of their typical workday. Data was collected at the bumper assembly line, where cables are mounted onto the bumpers using connectors and clips. Participants were recruited through the local team leader among the team members who happened to be working during the scheduled data collection. Since participants were required to wear eye-tracking glasses during data collection, full vision or corrected to full vision using lenses constituted inclusion criteria. All participants were experienced workers with two or more years of experience as Volvo employees and nine or more months of experience working at the precise workstation.

Workers that showed an interest in participating were verbally informed about the study, asked to sign written informed consent, and thereafter asked to wear a pair of eye-tracking glasses (Pupil Labs Invisible). After a quick calibration of the eye-tracker made by one of the researchers, the data recording was initiated, including both eye-gaze data and the front-facing camera on the glasses. Each recording session lasted for about 15 minutes during which the participant was asked to continue working as usual.

Results and Discussion 57 assemblies, about 30 seconds each, were recorded, comprising a total of 1340 high-phased assembly operations such as reach to grasp, placement of components, screwing, and finger press. For each operation, the time of first fixation on the target and the time of hand contact with target was manually annotated by the second and forth author, using the ELAN video annotation tool. In order to assess reliability, 30 recordings were annotated by both annotators, revealing very high reliability (Krippendorff Alpha > 0.99). An example frame from the front facing camera is presented in Figure 1A.

The 57 analysed assemblies comprised a total of 3793 fixations, identified by velocity threshold (IVT) using the Pupil Cloud software. 35% of these fixations were directly associated with a specific annotated hand action, and thus identified as proactive gazes.

The distribution of PEG intervals is presented in Figure 1B, revealing a pattern of very stable proactive eye-movements towards the target location, mean = 794 ms, median = 707 ms, std = 524 ms. The vast majority (97.4%) of all fixations appeared at least 200 ms before of the first hand contact with the target. A large proportion of the remaining 2453 fixations that were not identified as proactive gazes were also related to the task, and many of these fixations preceded the hand actin in close proximity of the target.

Individual variations were also small. As visible in Figure 1C, each of the four participants produced a similar PEG distribution, with means ranging from 743 ms to 852 ms. Acknowledging that the number of participants were very small, the general implications of these findings should however be taken with care.

Contrary to our hypothesis, these results show similar, or possibly even stronger, proactive eye-gaze than found in previous investigations, suggesting that PEG is at least as prominent in repetitive actions as in other contexts. These results indicate that PEG could constitute a reliable queue for upcoming actions also in very repetitive situations, with high phased actions.

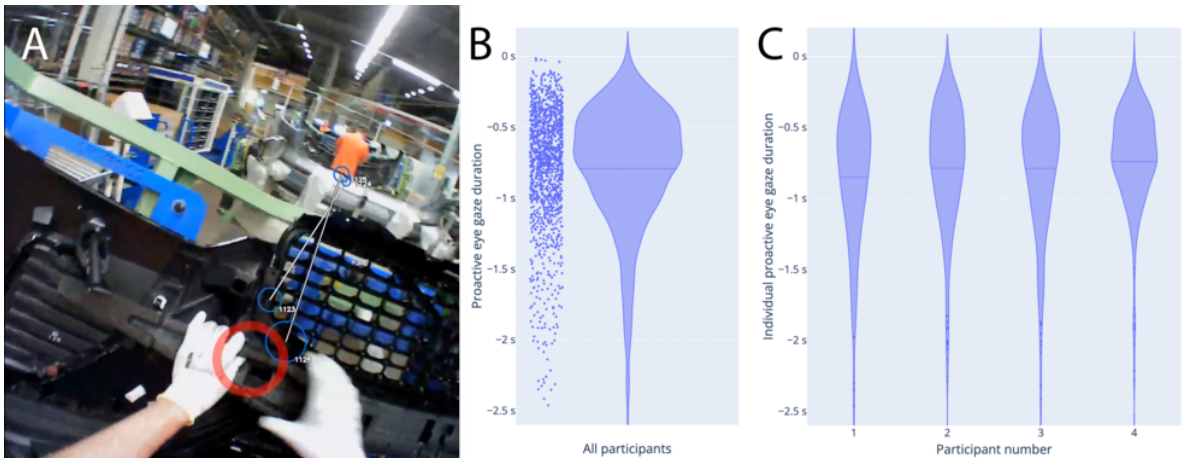

Figure 1: (A) The workers view during assembly captured with the front-facing camera of the eye-tracking glasses. Courtesy of Volvo Cars. (B) and (C) Temporal distribution of proactive eye-gazes, in relation to first hand contact with target.

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