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Assessing Graphical Robot Aids for Interactive Co-working

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Abstract. The shift towards more collaborative working between humans and robots increases the need for improved interfaces. Alongside robust measures to ensure safety and task performance, humans need to gain the confidence in robot co-operators to enable true collaboration. This research investigates how graphical signage can support human–robot co-working, with the intention of increased productivity. Participants are required to co-work with a KUKA iiwa lightweight manipulator on a manufacturing task. The three conditions in the experiment differ in the signage presented to the participants – signage relevant to the task, irrelevant to the task, or no signage. A change between three conditions is expected in anxiety and negative attitudes towards robots; error rate; response time; and participants' complacency, suggested by facial expressions. In addition to understanding how graphical languages can support human–robot co-working, this study provides a basis for further collaborative research to explore human–robot co-working in more detail.

Keywords: Human–Robot Interaction · Graphical Signage · Anxiety towards Robots · Negative Attitudes towards Robots · Trust · Manufacturing Tasks · Co-Working

1 Introduction

Robots are becoming more than passive/programmed or autonomous tools for humans to use; as they become more sophisticated and automated co-working partners, the relationship between humans and robots will change to more resemble interaction between two individuals [1]. This shift in industry for manufacturing tasks to incorporate human–robot co-working increases the need for improved interfaces to make this interaction more efficient. As the requirements on autonomy, complexity and safety of robots increase, human operators need to gain confidence in robots and their capacities to enable true collaboration. These issues are exacerbated by the introduction, and up-skilling, of workers without robotics experience. These factors increase the need for effective information communication to users to aid human–robot interaction in manufacturing settings. One reliable and effective means to clearly and rapidly communicate necessary information is through graphical signage.

A main aim of signage is to provide information, and by providing information to allow people to respond to a given situation or instruction in appropriate manner, with confidence. Graphical signage as a means of communicating can be especially beneficial in industrial settings, if designed according to ergonomic rules and principles [2][1]. One of the most important aspects of signage design is to communicate information in a quick and concise manner. Graphical signage can decrease the time necessary to navigate in unfamiliar locations when signage is displayed compared to when there is no signage present [4, 5]. Furthermore, in manufacturing and road/highway settings, where information has to be presented in a quick and clear way, effectively designed signage can reduce the number of accidents [6, 7]. One of the possible reasons for this decrease is the decline in cognitive load required as the individual has to process smaller amounts of information before making a decision [8].

Graphical instructions are one of the most efficient methods of displaying instructions for individuals with little or no prior-experience [9]. Examples of this approach include the instructions for assembling Ikea furniture; non-skilled individuals manage to assemble furniture by following visual instructions with no or little text-based explanations. Moreover, this kind of symbol based instruction can be universal: understood across cultures and not dependent on written language [10]. Finally, succinct, clear symbolic displays in the work environment can benefit not only non-native language speakers, but also individuals with learning disabilities such as dyslexia [11]. Combining easy readability and a clear message is an effective way of delivering information.

Besides physical factors, graphical languages in human–robot co-working can reduce human psychological distress and help workers to adapt to the changing scenarios in the work place. As discussed, graphical signage is often designed to help people understand the requirements of unfamiliar situations, which can lead to greater empowerment and a sense of control. In a healthcare context, well-designed booklets and information leaflets can not only make patients aware of facts and give advice, but also encourage discussion and prompt questions [12]. Furthermore, leaflets that encourage patients to raise issues and discuss symptoms in the consultation process can improve patient satisfaction and perceptions of communication [13]. Access to information relating to a patient’s condition and treatment has been shown to lead to a feeling of more control and greater empowerment [14]. This informed sense of empowerment and control can decrease the levels of stress experienced [15–17].

Higher stress and anxiety levels can be triggered by perceptions of danger and insecurity [16, 18]. Following on from this, anxiety and negative attitudes can influence trust levels [19] which are important not only for collaboration in the social context of human-human interaction [20–22], but also for human–robot interactions in collaborative manufacturing tasks [23, 24]. In the manufacturing context, without clear instructions and training, an individual’s cognitive load is often already high [25] and there can be little capacity beyond undertaking a complex activity for monitoring coworkers while performing an industrial task. In addition, stress and decision-making anxiety can influence mental and physical illnesses [26], and it is expected that reduc-

[1] Though care must be taken in designing signage to reduce ambiguity in interpretation [3].

ing uncertainty through the use of graphical signage can help improve the mental and physical well-being for the individual.

Although past research shows that experience of human-robot interaction can decrease participants' negative attitude towards robots [27], this decrease in anxiety depends on the robot's behavioral characteristics [28], and the individuals expectation of the experience and interaction, which can be communicated and prefigured by the use of graphical signage [29]. In this project, the use of the graphical signage is expected not only to aid human–robot collaboration to help achieve higher production levels in a shorter time, but also to decrease uncertainty and anxiety, leading to safer and healthier working environments. The aim of this project is to investigate whether and how graphical signage can aid human–robot interaction in the manufacturing context. This will be achieved by observing human participant behavior in the manufacturing context under three signage display conditions: relevant to the task, irrelevant to the task, and no signage.

2 Methods

2.1 Experimental Design

This study will use a mixed design of three independent conditions: signage relevant to the task (experimental), signage irrelevant to the task (active control), and no signage (baseline control). Repeated measures within conditions will be used: participants first complete baseline measures of attitudes and anxiety towards robot (see section 2.5 Measures) and again after the robot interaction scenario.

2.2 Participants

Ninety students from the University of Sheffield will be recruited to participate in the study (30 participants per condition). They will have normal or corrected-to-normal vision, no emotional and learning disorders and be between 18 and 35 years old. Participants' experience of working with robots, programming and computer usage, risk taking attitude, and anxiety and negative attitudes towards robots will be accounted for between the groups. Participants will be offered an opportunity to win one of five £10 Amazon vouchers for their participation in the study. It will be emphasized that the possibility to win will not dependent on their performance but on participation in the experiment. The study has been approved by the University of Sheffield ethics committee.

2.3 KUKA iiwa Lightweight Arm

In this study, a KUKA Intelligent Industrial Work Assistant (iiwa) will be used for the human–robot co-working task. The KUKA iiwa is a lightweight robot for industrial tasks developed by KUKA Robotics Group (KUKA Roboter GmbH). The design of this robot is based on a human arm with seven axes of movement and it is able to lift up to 7 kg of weight (Fig. 1). The KUKA iiwa is developed as a collaborative robot, specifically allowing direct human–robot interaction, and has a set of configurable safety measures suited to co-working. For this study the robot will be set to be operated in a compliant safe mode 'T1' with limits on speed and a requirement for human monitoring.

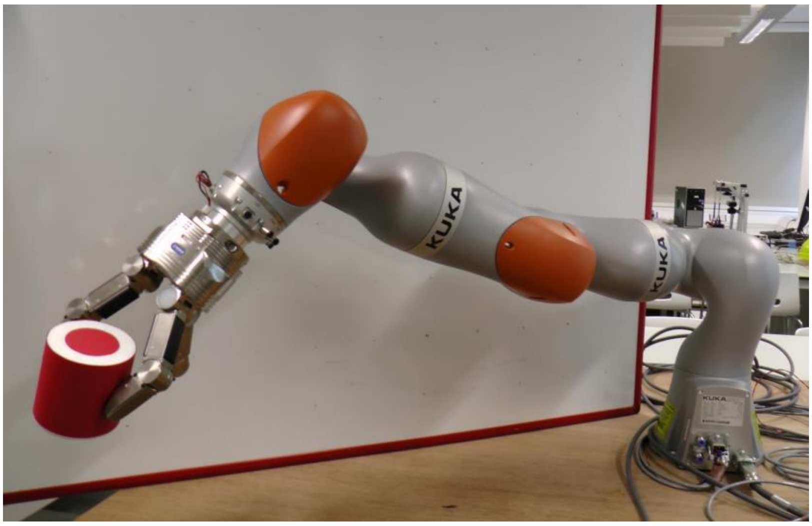

Fig. 1. KUKA iiwa.

2.4 Design of the Graphical Signage

For the project a bespoke set of graphical symbols are being developed to test the research proposition. In developing the look and feel of these new signs ISO graphical signage conventions have been considered [30]. The project designers have undertaken experimental designs with different visualization options (see Fig. 2). These are refined in consultation with the broader project community. Consideration as to where signage should be placed in the experiment, size and form (digital or physical) has also been undertaken.

The intension is that the project symbols will form the foundation for a larger system of symbols that can be used for a range of human – robot interaction scenarios. For this specific experiment, how to visually represent the following key human – robot interaction events have been considered, to help inform a co-worker that:

1. You can touch the robot
2. You will be within its' area of operation
3. The robot arm will move along the x and y axis
4. The robot arm will move at a certain speed
5. In your interaction with the robot arm there will be active and passive states
6. You should use a certain amount of force to move the robot arm

7. The robot will have a certain amount of force

Due to experimental design, two sets of signage have been developed – signage representing the necessary knowledge required to co-work with the robot (for example, speed, and reach parameters of the robot; Fig. 2) and signage which does not provide task-specific information for the robot user (for example, optimal temperature for the robot to operate).

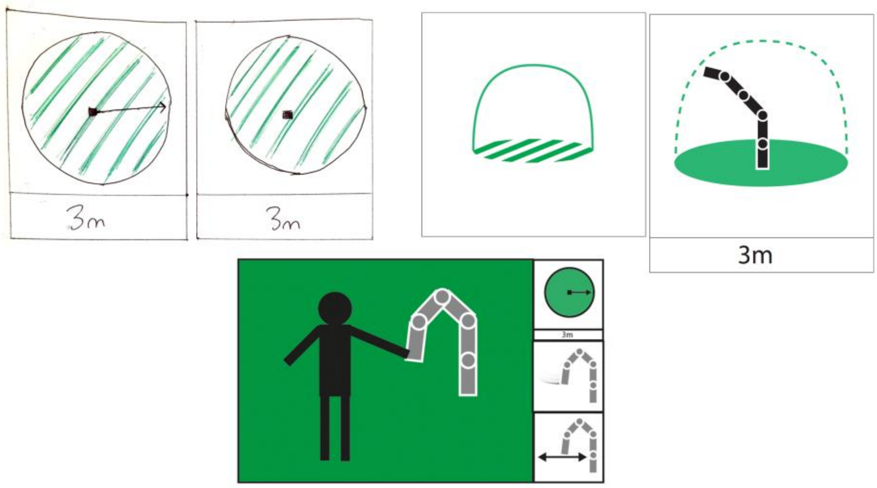

Fig. 2. **Examples of graphical signage at the early development stage.**

2.5 Measures

Negative Attitudes towards Robots Scale (NARS). This scale consisting of 14 statements was developed by [31]. Here participants indicate their level of agreement on each statement on a five-point scale (from 1 – strongly disagree to 5 – strongly agree). NARS is composed of three sub-scales; measuring negative attitudes towards interaction with robots, towards social influences of robots, and towards emotions in interactions with robots. In this experiment the sub-scales of attitudes towards interactions with robots and towards social influences will be administered pre- and post-experiment.

Robot Anxiety Scale (RAS). This scale measures anxiety affecting participants' interactions with robots [32]. The scale is divided into three sub-scales measuring participants' anxiety towards the communication capability of robots, behavioral characteristics of robots and discourse with robots. As the current experiment will be measuring participants' performance on a manufacturing task, only the sub-scale measuring anxiety towards the behavioural characteristics of robots will be conducted pre- and post-experiment. In this questionnaire, participants indicate how anxious they feel about each statement on a six-point scale from 1 "I do not feel anxiety at all" to 6 "I feel very anxious".

Risk Taking Index (RTI). A six statement scale assessing participants' everyday risk taking attitudes now, and in the past, on a five point scale (1 – never, 5 – very often) was developed by [33] and will be administered pre-experiment.

Experience with Robots. This scale containing 5 questions assesses how often participants attended robot-related events, read literature, watched media, had physical contact with a robot, or have built or programmed a robot [34]. Participants will indicate their answers on a 6-point scale (0, 1, 2, 3, 4, 5 or more times) before interacting with robot.

Graphical Signage Effectiveness. This scale was adapted from the Experimental and Survey Studies on the Effectiveness of Dynamic Signage Systems in the context of fire safety [35] to fit robot related material. The questionnaire contains two subscales; three statements assess participants' perceived general effectiveness of signs, and five statements assessing effectiveness of the signage on the purpose of assisting people in interacting with the robotic arm. Participants indicate how much they agree with each statement on a 5-point scale (from 1 – strongly agree to 5 – strongly disagree. An additional option indicating that they did not see any graphical signs was added for the benefit of the control condition with no signage). Participants will fill in this scale after interacting with the robot.

In addition to the previously mentioned measures, prior to the experiment participants will be asked to indicate how many hours per week they use computer for assignments/work, for browsing/socializing, and for playing computer games (indicating which category of games they prefer). Their programming expertise will be self-assessed on a 5-point scale (1 – very inexperienced, 5 – very experienced). After they have completed the main experimental task and the graphical signage effectiveness questionnaire, they will have to indicate which signs they had seen during the experiment.

All the questionnaires in this study are computerized and will be presented through the Qualtrics Insight Platform.

Behavioral Measures. The following behavioral measures will be recorded throughout interaction: 1) participant error rate, 2) time taken to complete the task, 3) participant facial expressions during success and fail attempts to complete a single trial/industrial part, 4) count of instances participants turn away from the robot while the robot is operational. Measures 1 and 2 serve as behavioral indexes of task achievement. Measures 3 and 4 serve as behavioral indexes of participants' anxiety towards working with the robot. Facial expressions (mean intensity and duration) are coded automatically with Noldus FaceReader version 5; FaceReader offers automated coding of expressions at an accuracy comparable to trained raters of expression [36].

2.6 Procedure

After signing the consent form, participants will be sent a hyperlink to an online questionnaire to fill in before taking part in the main experiment. The questionnaire will measure the participant's robot anxiety (RAS), negative attitude towards robots

(NARS), computer usage, computer game and programming experience, risk taking attitude (RTI) and experience with robots.

When participants come to the main part of the experiment, participants are told they are going to be co-working with the KUKA robotic arm on a task requiring human-robot interaction. They will be told that on the table there are 16 holes with narrow tubes and 6 of them contain small, industrial parts. These parts need to be put into a collection box. The industrial parts are inaccessible to the human (placed in narrow and long tubes), however the robotic arm can access them. Although the arm can reach and pick the objects, it is unable to locate the exact tubes where the industrial parts are needed, the participants help is required to locate them. The participants can only complete the task by collaborating with the robotic arm. The maximum time to complete the task is 15 min. During the experiment, a collaborator observes the participants' performance behind closed curtains as a safety measure in case the experiment needs to be aborted.

Participants are informed that they are going to be video recorded during the experiment, and the material collected will be used for data coding and further statistical analysis. However, measures are taken to keep the data anonymous and confidential.

After the main part of the experiment is completed, participants complete an online questionnaire measuring their perceived effectiveness of graphical language and recollection of the signage they have seen during the experimental task with robot. Their robot anxiety (RAS) and negative attitudes towards robots (NARS) are measured once again. Finally, participants are debriefed explaining the aims of the experiment. The whole experiment lasts about 30 minutes.

3 Anticipated Outcomes

The expected results from the study include observing decreased error rate and task completion time in the experimental group compared to the active control and control groups. This effect has been observed in human navigation studies of unfamiliar environments [4, 5]. Furthermore, past research shows that after having interacted with robots, participants' negative attitudes towards robots decrease [27], however the decrease of the anxiety also depends on the robot's behavioral characteristics [28]. Therefore, we expect that participants' anxiety levels and negative attitudes towards robots will decrease after the interaction with robot. This effect should be stronger in the experimental group, as the signage will influence their expectation of robot abilities and maneuverability [29]. Following this, the experimental group participants are expected to have turned their back towards robot on more occasions, compared to control groups, thus indicating higher levels of trust.

4 Predicted Implications

At the time of this paper being written, the results for this study are only being collected; therefore only the predictions of what we expect to see are discussed. In addition, the investigation uses a novel approach and the research question has not been explored previously which leaves some of the predictions exploratory and can only be speculative until all the data is collected and analyzed.

However, if the initial study predictions prove to be accurate, we should be able to observe how graphical signage related to the robots working characteristics can make human–robot co-working more efficient. First, by decreased error rate and the time necessary to complete the task. Second, decreased anxiety and negative attitudes towards robots and an increase in operator confidence should result in less human psychological distress in the work environment. Following this, an increase in the number of times individuals turn their back towards the robot during the co-task should also indicate more trust and comfort in co-working with the robot. Overall, these factors should reveal that the general mental state of the operator is more positive and that they feel more comfortable co-working with a robot on manufacturing tasks. Furthermore, this might influence greater levels of attention and concentration in the work setting. Decreased attention and cognitive function has been observed to be related to the number of minor injuries and even accidents at work [37]. Therefore, it is hoped that the use of a graphical language in the human–robot interaction might have some influence in deceasing workplace accidents. However, this would need to be explored in future studies. Further investigations will also examine what environmental factors are required to maximize the advantageous effect of graphical signage.

In summary, we expect that the use of graphical signage will have a positive effect not only for manufacturing industry, but also for people working in these settings, potentially increasing production by reducing levels of anxiety, and increasing trust towards robots in co-working scenarios.

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References

1. Ososky, S., Schuster, D., Phillips, E., Jentsch, F.G.: Building appropriate trust in human-robot teams. In: 2013 AAAI Spring Symposium Series (2013).
2. Chan, A.H.S., Ng, A.W.Y.: Investigation of guessability of industrial safety signs: Effects of prospective-user factors and cognitive sign features. Int. J. Ind. Ergon. 40, 689–697 (2010).
3. Frixione, M., Lombardi, A.: Street Signs and Ikea Instruction Sheets: Pragmatics and Pictorial Communication. Rev. Philos. Psychol. 6, 133–149 (2015).
4. Tang, C.-H., Wu, W.-T., Lin, C.-Y.: Using virtual reality to determine how emergency signs facilitate way-finding. Appl. Ergon. 40, 722–730 (2009).
5. Vilar, E., Rebelo, F., Noriega, P.: Indoor Human Wayfinding Performance Using Vertical and Horizontal Signage in Virtual Reality: Indoor Human Wayfinding and Virtual Reality. Hum. Factors Ergon. Manuf. Serv. Ind. 24, 601–615 (2014).
6. Bahar, G., Masliah, M., Wolff, R., Park, P.: Desktop reference for crash reduction factors. (2007).

7. Laughery, K.R.: Safety communications: Warnings. Appl. Ergon. 37, 467–478 (2006).
8. Chen, R., Wang, X., Hou, L.: Augmented Reality for Collaborative Assembly Design in Manufacturing Sector. Virtual Technol. Bus. Ind. Appl. Innov. Synerg. Approaches Innov. Synerg. Approaches. 105 (2010).
9. Tufte, E.R.: The visual display of quantitative information. Graphics Press, Connecticut (1993).
10. Ben-Bassat, T., Shinar, D.: Ergonomic Guidelines for Traffic Sign Design Increase Sign Comprehension. Hum. Factors J. Hum. Factors Ergon. Soc. 48, 182–195 (2006).
11. Lamont, D., Kenyon, S., Lyons, G.: Dyslexia and mobility-related social exclusion: the role of travel information provision. J. Transp. Geogr. 26, 147–157 (2013).
12. Mills, M.E., Sullivan, K.: The importance of information giving for patients newly diagnosed with cancer: a review of the literature. J. Clin. Nurs. 8, 631–642 (1999).
13. Little, P., Doward, M., Warner, G., Moore, M., Stephens, K., Senior, J., Kendrick, T.: Randomised controlled trial of effect of leaflets to empower patients in consultations in primary care. BMJ. 328, 441–0 (2004).
14. Ussher, J., Kirsten, L., Butow, P., Sandoval, M.: What do cancer support groups provide which other supportive relationships do not? The experience of peer support groups for people with cancer. Soc. Sci. Med. 62, 2565–2576 (2006).
15. Lautizi, M., Laschinger, H.K.S., Ravazzolo, S.: Workplace empowerment, job satisfaction and job stress among Italian mental health nurses: an exploratory study. J. Nurs. Manag. 17, 446–452 (2009).
16. Ozer, E.M., Bandura, A.: Mechanisms governing empowerment effects: a self-efficacy analysis. J. Pers. Soc. Psychol. 58, 472 (1990).
17. Pearson, L.C., Moomaw, W.: The relationship between teacher autonomy and stress, work satisfaction, empowerment, and professionalism. Educ. Res. Q. 29, 37 (2005).
18. Mathews, A., Mackintosh, B.: A cognitive model of selective processing in anxiety. Cogn. Ther. Res. 22, 539–560 (1998).
19. Kenworthy, J.B., Jones, J.: The Roles of Group Importance and Anxiety in Predicting Depersonalized Ingroup Trust. Group Process. Intergroup Relat. 12, 227–239 (2009).
20. Balliet, D., Van Lange, P.A.M.: Trust, conflict, and cooperation: A meta-analysis. Psychol. Bull. 139, 1090–1112 (2013).
21. King-Casas, B.: Getting to Know You: Reputation and Trust in a Two-Person Economic Exchange. Science. 308, 78–83 (2005).
22. van 't Wout, M., Sanfey, A.G.: Friend or foe: The effect of implicit trustworthiness judgments in social decision-making. Cognition. 108, 796–803 (2008).
23. Cameron, D., Aitken, J.M., Collins, E.C., Boorman, L., Chua, A., Fernando, S., McAree, O., Martinez-Hernandez, U., Law, J.: Framing Factors: The Importance of Context and the Individual in Understanding Trust in Human-Robot Interaction.
24. Hancock, P.A., Billings, D.R., Schaefer, K.E., Chen, J.Y.C., de Visser, E.J., Parasuraman, R.: A Meta-Analysis of Factors Affecting Trust in Human-Robot Interaction. Hum. Factors J. Hum. Factors Ergon. Soc. 53, 517–527 (2011).

25. Thorvald, P., Lindblom, J.: Initial Development of a Cognitive Load Assessment Tool. In: The 5th AHFE International Conference on Applied Human Factors and Ergonomics, 19-23 July 2014, Krakow, Poland. pp. 223–232. AHFE (2014).

26. Moreno-Jiménez, B., Rodríguez-Carvajal, R., Garrosa Hernández, E., Morante Benadero, M.A., others: Terminal versus non-terminal care in physician burnout: the role of decision-making processes and attitudes to death. Salud Ment. 31, 93–101 (2008).

27. Stafford, R.Q., Broadbent, E., Jayawardena, C., Unger, U., Kuo, I.H., Igic, A., Wong, R., Kerse, N., Watson, C., MacDonald, B.A.: Improved robot attitudes and emotions at a retirement home after meeting a robot. In: RO-MAN, 2010 IEEE. pp. 82–87. IEEE (2010).

28. Nomura, T., Shintani, T., Fujii, K., Hokabe, K.: Experimental investigation of relationships between anxiety, negative attitudes, and allowable distance of robots. In: Proceedings of the 2nd IASTED international conference on human computer interaction, Chamonix, France. ACTA Press. pp. 13–18. Citeseer (2007).

29. Muir, B.M.: Trust between humans and machines, and the design of decision aids. Int. J. Man-Mach. Stud. 27, 527–539 (1987).

30. ISO 3864-1: Graphical symbols - Safety colours and safety signs -Part 1: Design principles for safety signs and safety markings. Downloaded at 2016-01-08.

31. Nomura, T., Suzuki, T., Kanda, T., Kato, K.: Measurement of negative attitudes toward robots. Interact. Stud. 7, 437–454 (2006).

32. Nomura, T., Suzuki, T., Kanda, T., Kato, K.: Measurement of anxiety toward robots. In: Robot and Human Interactive Communication, 2006. ROMAN 2006. The 15th IEEE International Symposium on. pp. 372–377. IEEE (2006).

33. Nicholson, N., Soane, E., Fenton-O'Creevy, M., Willman, P.: Personality and domain-specific risk taking. J. Risk Res. 8, 157–176 (2005).

34. MacDorman, K.F., Vasudevan, S.K., Ho, C.-C.: Does Japan really have robot mania? Comparing attitudes by implicit and explicit measures. AI Soc. 23, 485–510 (2009).

35. Galea, E., Xie, H., Lawrence, P.: Experimental and Survey Studies on the Effectiveness of Dynamic Signage Systems. Fire Saf. Sci. 11, 1129–1143 (2014).

36. Lewinski, P., den Uyl, T.M., Butler, C.: Automated facial coding: Validation of basic emotions and FACS AUs in FaceReader. J. Neurosci. Psychol. Econ. 7, 227–236 (2014).

37. Simpson, S.A., Wadsworth, E.J.K., Moss, S.C., Smith, A.P.: Minor injuries, cognitive failures and accidents at work: incidence and associated features. Occup. Med. 55, 99–108 (2005).