Potential of Smart Glasses in Manual Order Picking Systems

BRIGITA GAJŠEK¹ and NATAŠA VUJICA HERZOG²

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ABSTRACT

Full automation of order picking “man-to-goods” workplaces still will not be rational in the near future. Humans will stay central actors and as such, they will determine system’s effectiveness and efficiency. Order picking activities are labour intensive and time-consuming. Smart glasses are one of the possibilities to relieve order-picker’s hands, resulting in reduced time consumption. In the paper, we review scientific literature on use of smart glasses in manual order picking system and outline the opportunities for future research.

Available scientific papers on smart glasses topic deal with unique environments characterized by layout, equipment, process, specific combination of technologies etc. Most authors agree that their findings cannot be generalized. There are no studies in the literature on the effects of multiple-hour use of smart eyeglasses on the eyes.

Warehouse systems are mostly not identical, even employees have different characteristics and attentiveness to technology. It is proposed to test each system before implementation and try to combine technologies for best results. Different systems tend to different goals, for example fast service or zero errors. The production system’s outputs are also very likely influenced by software and user interface design, which indicates the need for additional research. The growing number of studies certainly have a positive impact on clarifying the unexplored. The area of smart glasses currently represents a great research potential.

INTRODUCTION

Order picking is the process of retrieving items from their storage locations in a warehouse to fulfil customers’ orders [1]. In case of manual procedure, its activities are labour-intensive, even 1,500 picks per person per shift, and time-consuming. According to various authors, who mostly cite the same a bit outdated source [2], [3], mentioned activities account for more than 50% of warehouse operating costs. This ranks order picking as the most expensive warehouse operation, directly linked to customer satisfaction. Any wrong pick would lead to an unhappy customer and additional costs. More than 80% of all orders processed by warehouses are picked manually [4], [5]. Despite automation and use of robots in warehouse processes, large

¹Faculty of Logistics, University of Maribor, Mariborska 7, 3000 Celje, Slovenia
²Faculty of Mechanical Engineering, University of Maribor, Smetanova ul. 17, 2000 Maribor, Slovenia
share of all orders will still remain picked manually also in near future due to the exceptional qualities of human work [6]. On the other hand, unreliable nature of man, as well as the change in the availability of employees, caused by demographic changes will increasingly promote multi-level forms of cooperation between man and machine [7]. In this way, new technologies need to be developed.

Manual order picking is intensively researched from several perspectives, for example technical, organizational, ergonomics and other [6], with the aim of reducing costs. Depending on the industry sector, logistics costs amount 5 to 8% of revenue [14]. Recently, this goal extends even to maintain the health of employees. To this end, researchers are trying to shorten the path, reduce fatigue, speed up the acquisition of information about the next pick, and reduce the number of missing or incorrect pickings. The number of picks and quality to which order-pickers are able to carry out picking tasks is connected to what information they receive as well as its’ accuracy and how it is interpreted. Customer’s order can be assigned to order-picker either as a printed list or digitally via WLAN onto one of the following end devices: a handheld barcode scanner, head mounted device (HMD) like smart glasses, a pick-by-light system or pick-by-voice system. In general, the most time-consuming is reading data from paper. Although commonly used in practice, other modes are still in the testing and research phase. The latest method is to use smart glasses. By definition, smart glasses are a technology that enhances reality by displaying additional information on top of it [8]. They proved useful for managing fieldwork from the central organizational unit. In this way, one top expert can do more work with the help of geographically dispersed less skilled assistants or even the users themselves. The potential of providing experience-based information by use of smart glasses is noticed. Although correlations between smart glasses and productivity/quality/ergonomics exist, for example full-scale implementations of the technology in a distribution center is not motivated [8]. The adoption of information and communications technology into manufacturing industry, which is possible for example also with the use of smart glasses as a communication media, is also a starting idea of today massively researched industry 4.0 which largely base on lean initiative [9].

It is frequently mentioned, that technology is rapidly developing and that smart glasses hold a large potential in the future [8]. This paper contributes to faster clarifying the opportunities and pitfalls in the use of smart glasses in order-picking systems. For this purpose, the following research questions are answered:

\textit{RQ1: What are the main findings of research on the topic of smart glasses in the field of logistics, as a wider area, which includes order picking?}

\textit{RQ2: To what extent are findings found useful for designing order picking systems?}

\textit{RQ3: What kind of questions would it make sense to look for answers in the future?}

**METHODOLOGY**

Conducting a systematic literature review constitutes a comprehensive approach to map out the content of the research work in the field of HMDs in manual order picking by scoping its domain and core issues. This paper is based upon a review of scientific articles identified in relevant journals across the fields of order picking, man-to-goods, smart glasses, data glasses and HMD. During the research work, no previous literature review was found. Overall, this paper makes contribution by summarizing partial findings on various studies in specific environments and links debates on knowledge
creation to the field of HMDs in manual order picking. It does not pretend to cover the entirety of the literature but rather offer an informative evaluation of purposefully selected literature in mentioned area, which will serve to answer previously outlined research questions. We were not limited to certain time-period, although we were most interested in current dialogue. The review has been limited to peer-reviewed publications as a way to guarantee a certain level of quality [10], and to ensure consistency between the themes and sources by carefully selecting journals. A closer analysis of the abstracts allowed distinguishing between relevant and irrelevant articles.

SMART GLASSES IN SCIENTIFIC LITERATURE

All systems using Head-mounted displays (HMDs) to support the order picking process are named pick-by-vision systems. Pick-by-vision systems are further subdivided according to the making use of tracking technologies [11]:

- pick-by-vision (2D) systems (user position is not tracked, textual information in a form of a list of items or images is presented to the user);
- pick-by-vision (AR) systems (use tracking and make explicit use of augmented reality\(^3\) (AR); consist of following parts [16]: display, computer, input device and tracking system).

Smart glasses, also named as data glasses, are an example of HMD.

Peli [12] researched Visual issues in the use of HMD already in 1990. Findings (Table 1), that base on max 20 minutes tests in laboratory environment, did not reveal any potential harmful effects, except not recommending use while driving. Six years latter Peli [13] wrote that the concerns about possible harmful effects are accompanying the introduction of almost any new wide-use-technology and HMD are not an exception. He concluded that it appears to be most appropriate to test each system separately. This will enable the developer to determine for each design that comfortable and safe use, by the target population and the intended use, is achievable.

Application of HMDs to support the order picking process was already researched before 2009 [11]. The authors compared the use of HMDs to established methods (paper, pick-by-light, pick-by-voice), which is even today a common practice in the academic sphere to motivate its capabilities, and checked the user strain besides the general performance. They were satisfied with results, which we present in table 1, although they were not statistically significant. Results largely depend on pick-by-vision system in a sense of input device, the number of system states to click through, reaction time to display information and imperfect guiding by the augmented reality visualization, lack of control mechanisms to monitor the work done. Authors concluded their report that slightly better results in comparison with established method are not enough to introduce and apply the technology in practice.

Approximately, in the same period, Weaver with coauthors [14] also noticed that use of their type of HMD performed better than the traditional method of text-based paper. Results cannot be generalized, because environment (Warehouse) layout affects the result of a comparison of different methods. Results also depend on participants who do not always take advantage of all of the optimization possibilities when using specific picking method.

\(^3\)The primary value of augmented reality is that it brings components of the digital world into a person's perception of the real world, and does so not as a simple display of data, but through the integration of immersive sensations that are perceived as natural parts of an environment (Wikipedia).
After 2010, smart glasses have been adopted as a safe enough technology for use in pilot projects. We begin to encounter more research that explores different technical designs and combine different technologies to achieve optimum work results. Rammelmeier et al. [16] reasoned about active prevention of picking errors by employing pick-by-vision systems, because known fact that humans receive more than 80% of the information through the visual sensory channel [17]. Authors confirmed with laboratory test, that the provision of information via HMD facilitates an accurate information reception. HMD enables permanent visibility of the instructions to the order-picker and not just for a short period, as it is in a case of pick-by-voice. Furthermore, the authors between other propositions (Table 1) suggest mandatory confirmation of an item by voice or a button in combination with checking numbers on the item.

Pickl [18] once more compared different methods, namely HMD, voice, paper, and projection. Once again, he proved that results are case sensitive. They depend on layout, characteristics of equipment, order picking process, users characteristics, items and other. Results are presented in Table 1. There is always a way to improve method’s shortcomings. Pick speed and accuracy with pick-by-vision systems can be improved by associating colors with shelves and shapes with bins [19].

Pick-by-paper, cheapest for implementation, and pick-by-light are currently widely used in industry. According to tests pick-by-vision with HMD and cart mounted display (CMD) are promising competitors for current industrial applications [20] what is slightly different suggestion as that one from [18]. Although most authors evaluate pick-by-vision system with HMDs as competitive, productive and promising technology, which hold large potential in the future, questions linked to the effects of long-term use are still unanswered [22].

Table 1. Sumarized findings from scientific research.

| Authors                      | Topic | Findings                                                                 |
|------------------------------|-------|-------------------------------------------------------------------------|
| Schwerdtfeger et al., 2009 [11] | *     | • HMD systems support the worker with just the right information at exactly the right time. |
|                              |       | • Pick-by-vision (AR) could\(^a\) have lower error rate than pick-by-vision (2D). |
|                              |       | • Pick-by-vision systems could\(^a\) have about 10% better picking time performance than that of the paper list. |
|                              |       | • After about half an hour with the system, subjects did not feel uncomfortable or constrained. |
|                              |       | • It was not indicated that working with pick-by-vision (AR) system caused a higher strain than use of paper list. |
|                              |       | • The errors for the pick-by-vision (AR) system decreased during runtime and increased for the paper list. |
|                              |       | • There are two groups of HMD users. One can make user input while walking and the other cannot. |
|                              |       | • Possible problems are headaches, pressure in eyes, problems focusing on the MHD, difficulties with text reading. |
| Peli, 1990 [12]              | *     | • Extended use of the monocular display may result in changes in the phoria posture and cause asthenopic symptoms. |
|                              |       | • Changes in phoria and fixation disparity are more likely |

\(^a\)Difference is not significant.
in people who are already symptomatic or who have various uncorrected visual deficits.

- Appearance of asthenopic visual discomfort symptoms in a user may be regarded a protective-screening effect, since it appears to uncover existing latent problems.
- Long-term effects are small, since it appears from the reviewed literature that the visual system tends to recover quickly when the monocular occlusion is removed.
- Although awareness of the environment is maintained when using the display, it is obviously unsafe to attempt to use some types of monocular display while driving.
- At work with researched HMD, there were no evidence of motion sickness or loss of postural stability in any of the users, standing or sitting.
- The image motion noted during saccades is small.
- Eye-dominance can potentially affect performance.

| Weaver et al., 2010 [14] | * | * | HMD (MicroOptical SV-6), as a part of pick-by-vision (AR) system performed better than the traditional method of text-based paper. The work was faster than with graphical paper/text-based/audio version. |
|------------------------|---|---|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Rammelmeier et al., 2011 [16] | * | | HMD enables permanent visibility of the instructions to the order-picker, which can results in a reduction in error rates. |
| Pickl, 2014 [18] | * | * | Results of comparison of different order picking methods strongly depend on the use-case. |
| * | | | For specific use-case projection method was the best one, in regard to overall errors, task completion time and overall usability. |
| * | | | Errors can be divided on cart, pick, filling, part and amount errors. At HMD method, the amount of amount errors and part errors is very low in comparison to paper/projection/voice method. Contrary the amount of filling and pick errors is high. |
| * | | | Use of HMD method resulted in a higher task completion time. |
| * | | | According to NASA Task load Index HMD method was the most demanding method for users. They would not want to use it for a whole workday. |
| Guo et al. 2014 [20] | * | * | HMD is faster than CMD, pick-by-light and pick-by-paper. |
| * | | | HMD is not harder to learn and no less comfortable than any other methods. |
| * | | | Wrong order bin errors happen more frequently for pick-by-paper. Missing part errors are frequent at |
pick-by-light. No substitution errors happened on HMD but they happened on CMD.

| Josefsson and Lingegard, 2017 [22] | * | * | * | * |
|-----------------------------------|---|---|---|---|
| • Compared to alternative methods, smart glasses enable higher quality. |
| • Regarding ergonomics, it was from literature concluded that smart glasses had great potential to reduce the cognitive load for the operators. |
| • Transmitted information that operators upload to the system is not an applicable information type for smart glasses. A complementary solution is needed. |
| • Displaying experience-based information was identified as the main potential for smart glasses. |
| • Adding too much or irrelevant information will have a negative performance impact. |
| • Displaying additional information during picking could help operator to pick with both better quality and better ergonomics. |
| • Flexibility could be achieved if operators or managers can do changes without consulting programmers, as long as the system supports that. |

*—topic included; P—productivity; Q—quality; E—ergonomics; F—flexibility; TC—time consumption

RESULTS

The purpose of this paper was to answer on in introduction posed research questions. To fulfill this purpose, scientific papers on HMD/pick-by-vision, smart glasses/data glasses have been studied.

RQ1: What are the main findings of research on the topic of smart glasses in the field of logistics, as a wider area, which includes order picking?

The main findings are summarized in Table 1. These findings are further divided into five subgroups according to the topic, namely productivity, quality, ergonomics, flexibility, time consumption. Most studies research ergonomic perspective and time-consuming perspective. We found only one work discussing about flexibility. Usually systems are built case-specific. Each scientific paper on our reference list deals with specific environment described with unique layout, equipment, process etc. Most authors agree that their results cannot be generalized. But it is possible to summarize the most frequently stated findings, which are more likely to apply to similar cases.

HMD systems support the worker with just the right information at exactly the right time. If this technology is used, the productivity can be most likely improved because order-pickers have both hands free for work. Mostly subjects feel comfortable when using HMD. Today’s models are lighter, ergonomically designed and can be customized to the user before work. There are two groups of HMD users. One can make user input while walking and the other cannot. It is important to employ people who do not have resistance to technology or serious visual problems. Possible problems because of work with HMD are headaches, pressure in eyes, problems focusing on the MHD, difficulties with text reading. Long-term effects are small, since it appears from the reviewed literature that the visual system tends to recover quickly when the monocular occlusion is removed. Although awareness of the environment is

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maintained when using the display, it is obviously unsafe to attempt to use some types of monocular display while driving. Testing before use is recommended.

Use of HMD can reduce error rate if the system is upgraded with a kind of control mechanism. Authors propose several on bases of testing. Time consumption can be lowered with SW solutions, proper design of displayed information in a sense of used colors, shapes and text high.

**RQ2: To what extent are findings found useful for designing order picking systems?**

After 2010, smart glasses have been adopted as a safe enough technology for use in pilot projects. In papers, we noticed several used in order picking systems. Results are only partly useful for designing order picking systems. Warehouse systems are mostly not identical, even employees have different characteristics and attentiveness to technology. It is proposed to test each system before implementation and try to combine technologies for best results. Different systems tend to different goals, for example fast service or zero errors. Testing and perhaps simulations will enable the developer to determine for each design that comfortable and safe use, by the target population and the intended use, is achievable.

**RQ3: What kind of questions would it make sense to look for answers in the future?**

A comparison of the use of different HMDs in the same system is missing in a scientific literature. That kind of research would show how big could be differences between HMDs regarding speed, error rate, ergonomics and productivity. Perhaps it would help to discover the reason for differences in results on HMDs between different papers comparing different methods.

The question whether it could be harmful for the human eye to work a full day with smart glasses or not is still unanswered [22]. Additionally some users experience serious problems using HMD. What are the effects of long-term use is still not clear enough. Further research would be welcome.

This are only two potential areas for further research. We are sure that summarized findings from scientific research in this paper will help reader to see potential for research according to his/hers area of expertise.

**CONCLUSIONS**

Smart glasses or data glasses are as a type of HMD just another piece of technological equipment with its own characteristics, advantages and disadvantages. Their current maturity is still not sufficient to motivate full-scale implementations in different industrial environments. Through years, they become lighter, smaller, flexible to user, more powerful, with better battery, graphics and display. They are still under development and certainly not in final version. The lack of standard gives rise to the diversity of models. The researchers have plenty of work with comparing the use of different HMDs to established methods (paper, pick-by-light, pick-by-voice, pick-by-projection, and pick-by-CMD) and between themselves, which is a common practice in the academic sphere to motivate its capabilities. Results can be very contrary. Some users would not want to use HMD for a whole workday, while others can use them continuously over weeks [21]. The growing number of studies certainly
have a positive impact on clarifying the unexplored. The area of smart glasses currently represents a great research potential.

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