III. PERFORMANCE COMPARISON OF VARIOUS ORDER PICKING METHODS IN DIFFERENT BEHAVIORAL CONTEXTS

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Abstract

Three manual picker-to-parts order picking methods (parallel picking, zone picking, and dynamic zone picking) are employed in an experimental warehouse setup and compared in terms of productivity, quality, and job satisfaction. Participants worked in teams and were subject to either an individual-based, or a team-based incentive scheme. Furthermore, the influence of individual participants' dominant regulatory focus (promotion or prevention) was taken into account. The outcomes show that in parallel picking an incentive system focused on individual performance is beneficial for productivity and quality compared to an incentive system focused on team performance, whereas team-based incentives are more productive in zone picking. These results were more explicitly present for participants with a dominant promotion focus. Participants with a dominant prevention focus picked more productively with team-based incentives in all picking methods. In addition to this, team-based incentives led to a relatively high quality in zone-picking, but a relatively low quality in dynamic zone picking. Our study shows that assigning the right people to the right picking task with a fitting incentive system can substantially cut wage costs without simultaneously harming productivity, quality, or job satisfaction.

1 Introduction

In a time of global economic downturn, it is essential for warehouses to find out how operating costs can be reduced to remain competitive. All of this is taking place while the market share of e-commerce is growing, which often implies that warehouses have to meet increasing customer demands by offering speedier delivery and tighter and more flexible delivery windows [1]. This puts pressure on virtually all warehouse processes.

One of these processes, order picking, *the retrieval of a number of products from their storage locations in the warehouse to satisfy orders of specific customers*, is an essential activity in the supply chain and accounts for up to 50% of the operating costs of a typical warehouse (Tompkins 2010). Due to this relatively large share of costs, order picking is an attractive area to take into consideration when searching for productivity improvements and potential cost-savings. Selecting an appropriate order picking method is instrumental in achieving this.

Most of the academic literature on order picking focuses on optimizing a specific aspect of a particular order picking method. Examples include routing [3]–[5], storage assignment [6], warehouse layout [7], and zoning [8], [9]. This body of research is a major contribution to the field and has led to greater efficiency in those warehouses that have been able to successfully implement the findings in practice. However, surprisingly enough, one very important factor in order picking has been largely ignored: the people involved in order picking. De Koster et al. (2007) reported that less than 30 percent of the papers included in their literature review on warehouse order picking concerned *picker-to-part* order picking systems. This is probably because *parts-to-picker* systems are largely automated, which makes it easier and more attractive for researchers to accurately model the behavior of these systems. However, most warehouses employ people for order picking [10]. Unfortunately even the literature that does focus on picker-to-part order picking systems primarily studies system design, planning, and control related issues, rather than how humans act within these systems. This shows that the importance of the human factor in order picking is not acknowledged.

Through an experimental approach that was inspired by the recently emerged field of behavioral operations, this study aims to bridge the gap between traditional models focusing on optimizing the order picking process and the order picking performance that can actually be observed in practice. By taking behavioral aspects (i.e. incentive schemes and picker characteristics) into consideration, we aim to obtain results that directly translate into practice. The experimental approach of this current study, featuring a specially erected full-size warehouse, is highly novel and should ensure that our findings are, to a large extent, directly generalizable to the practical setting of warehouses worldwide.

2 Theory

2.1 Order Picking

As a pivotal step in a product's route to a customer, order picking can be regarded as the most crucial activity of all warehouse operations. The full order picking process involves all steps from clustering and scheduling customer orders to disposing the picked articles. In many of these steps, a certain degree of automation is possible, but most warehouses employ humans as order pickers [10]. In this paper, we focus on the most common picking system, low-level picker-to-parts picking with multiple picks per route, in which the order picker has to walk along the aisles to fulfill the order by picking all specified

items. This picking system contrasts with parts-to-picker systems that make use of automated storage and retrieval systems (AS/RS) or carousels [3].

Various technological picking tools can be used in low-level picker-to-parts systems. For example, pickers can be aided by hand-held scanners, voice-terminals, or pick-to-light systems. Here, we only focus on the traditional order picking using a paper picking list. There are also various picking methods. In this study we include three of the most common methods: parallel picking, sequential zone picking, and dynamic zone (bucket brigade) picking. In *parallel picking*, pickers work on their own order from the beginning to the end. This means that the pickers work almost independently of each other. In *sequential zone picking*, the warehouse or aisle is divided into separate zones. Each picker is responsible for one zone, and an order is passed on to the picker in the next zone when the order is completed in the zone. If an order does not contain any lines to be picked in a particular zone, the order is passed on to the next zone immediately. If the picker in the next zone is still busy with a previous order, the current order can be placed in a buffer. In *dynamic zone picking (bucket brigade picking)* the volume determines the end of the zone, so there is no fixed zone limit. Rather than waiting at the zone limit until the upstream picker is finished with his/her zone, a picker will travel towards the upstream picker and the order will be transferred at the meeting point. Theoretically, this eliminates waiting time or large buffers between zones [2].

2.2 Incentive Systems

Awarding financial incentives to reward performance is a common method to align the efforts of employees with the objectives of the company and to improve productivity and quality [11]. Previous studies have emphasized that financial incentives are among the most important drivers of employee performance [12]–[14]. Although some studies argue that offering external rewards such as money undermines intrinsic motivation [15]–[17], a meta-analysis of 39 studies by Jenkins Jr et al. (1998) showed a corrected correlation of .34 between financial incentives and performance quantity.

One of the most important considerations in implementing incentive systems is whether the organization should implement an incentive system that is completely based on individual performance, or rather adopt a team-based reward scheme in which the group performance determines at least part of the individual pay. Working in teams is increasingly prevalent in modern organizations, and individual incentive systems do not always fit well in that context [18]. Employees often have to execute interdependent tasks, and it can be difficult for a manager to evaluate the performance of an employee without considering the influence of direct colleagues [19]. The choice for either individual or team focused incentive systems is implicitly also the choice between highlighting the importance of either competition or cooperation among employees [20]. Whereas individual incentives can be expected to reinforce individual performance, team incentives may stimulate more cooperative behavior at group level [21]. The exact circumstances under which team incentives are more effective than individual incentives are unclear, but task interdependence has been identified as one of the most critical factors influencing the effectiveness of team rewards [22]. Task interdependence refers

to the degree of interaction and cooperation between team members that is required to complete a specific task [23]. The literature on the topic has consistently demonstrated that matching tasks and rewards lead to higher performance. This implies that it is more effective to use individual incentives for independent tasks, and group incentives for interdependent tasks.

If these findings are translated to the context of order picking, we can hypothesize which incentive system leads to better performance when used in combination with a particular order picking method. For example, a parallel picking system entails a relatively low degree of interdependence. Pickers work individually on a task, and are not required to communicate and coordinate work with other pickers. They know that they are responsible for their own performance, and are likely most motivated if the incentive system fits these circumstances, i.e. under an individual incentive system. An increase in motivation at work has commonly been linked to a variety of positive outcomes. Not only are motivated employees more productive, they most likely also work more precisely, and are more satisfied about their job [24]. Therefore, an individual incentive system is expected to perform especially well in the context of parallel picking, which is stated in the first hypothesis.

Hypothesis 1: In parallel picking, an individual-based incentive system will result in higher productivity, quality, and job satisfaction than a team-based incentive system.

In a zone picking system, pickers work in a team. Each picker only finishes part of an order and as a consequence the throughput time of an order is dependent on the performance of each individual picker. Moreover, the work one order picker can finish usually depends on the speed of the other pickers [25]. Thus, zone picking is associated with a high degree of task interdependency. Since high levels of task interdependency are a facilitator of the motivating effects of a group incentive system, pickers will probably be more motivated at work if the incentive system is group oriented to a certain extent as well. Since motivation should influence productivity, quality and job satisfaction it follows that the productivity performance, quality performance, and job satisfaction of pickers working with a zone picking method are higher under an incentive system that focuses more on team performance.

Hypothesis 2: In zone picking, a team-based incentive system will result in higher productivity, quality, and job satisfaction than an individual-based incentive system.

Dynamic zone picking is -to some degree- a combination of parallel picking (since pickers can autonomously determine where they hand over products to other pickers) and zone picking (with flexible zone boundaries). In other words dynamic zone picking includes both task elements that are independent in nature as well as task elements that are interdependent in nature. As a consequence we expect multiple effects in dynamic zone picking. On the one hand, the independent aspect of dynamic zone picking calls for an individual-based reward system. The cooperative aspect, on the other

hand, would better be served by a team-based incentive system. The net effect of the two counteracting mechanisms is unknown, and we have no theoretical grounds to make sensible predictions about this.

2.3 Regulatory Focus

Next to incentive systems we also focus on individual characteristics of pickers. To gain more insight in this issue we employ regulatory focus theory. This theory, first coined by Higgins (1997, 1998), is based in psychology and is well-suited to be employed in investigating any type of motivation [27]. Regulatory focus theory distinguishes between two self-regulatory strategies that influence behavior. A promotion focus emphasizes accomplishing desired, attractive, and positive goals and aims at achievement, growth, and advancement. A prevention focus emphasizes fulfilling duties, responsibilities, and obligations, and includes an element of fear of failing [27]. Also, prevention-focused people are often more risk-averse than promotion-focused people [28]. Although promotion and prevention focus are two theoretically distinct constructs, several studies suggest that an emphasis of one type of regulatory focus mitigates the effects of the other type [29], [30]. For example, a person with a dominant promotion focus is unlikely to be partly guided by a prevention focus at the same time. Because of this, we follow Lockwood et al. (2002) in expecting that the dominant regulatory focus of order pickers influences performance, rather than the individual effects of both regulatory foci.

In the context of order picking performance, we expect that the influence of each of the two regulatory foci partly depends on the type of performance. Prevention-focused people tend to follow rules and regulations conscientiously and to avoid errors [26], [32], which suggests that they could make fewer picking errors. A promotion focus, on the other hand, has been linked to production performance [32], [33] and to sensitivity to the presence or absence of rewards [34]. However, these results are not generally applicable, and are subject to a very influential factor: the fit between people's regulatory focus and the goal that they have to pursue [35].

Based on these findings we argue that the fit of the picking method and the incentive system is especially beneficiary if it also fits the regulatory focus of the picker. For example, the hypothesized better performance of parallel picking with an individual-based incentive system is expected to hold especially for more promotion-focused pickers, who generally place more emphasis on their own achievements and potential positive outcomes and thus are especially motivated by an individually oriented task and incentive system. In contrast, this method and this incentive scheme are expected to be a worse fit for more prevention-focused pickers. This is reflected in hypothesis 3.

Hypothesis 3: In parallel picking, pickers with a dominant promotion focus will perform better in terms of productivity, quality and job satisfaction with an individual-based incentive system than with a team-based incentive system, while no such difference exists for pickers with a dominant prevention focus.

Zone picking and a team-based incentive system, on the other hand, is a good combination especially for more prevention-focused pickers, who place more emphasis on team performance as we expect them to be especially motivated by a group-oriented task and incentive scheme. This combination is likely not so suitable for more promotion-focused pickers, who emphasize individual performance. Thus the difference between a team-based incentive system and an individual incentive system in zone picking is therefore most likely larger for prevention-focused pickers, while the incentive system is not expected to make a substantial difference for more promotion-focused pickers in zone picking. This leads to hypothesis 4.

Hypothesis 4: In zone picking, pickers with a dominant prevention focus will perform better in terms of productivity, quality and job satisfaction with a team-based incentive system than with an individual-based incentive system, while no such difference exists for people with a dominant promotion focus.

Dynamic zone picking is a mix of an individual and team picking method. As a consequence we argued earlier that both individual incentive schemes and group incentive schemes could be motivating in dynamic zone picking. Here we extend this reasoning by posing that the dominant regulatory focus of the pickers may determine which aspect of the task is the most salient and hence which incentive scheme would be more motivating with a dynamic zone picking method. For people with a dominant prevention focus, group aspects of the environment are most salient (Lee et al., 2000). Therefore, we also expect that for pickers with a dominant prevention focus the interdependent aspects of dynamic zone picking would be highly salient and consequently that a group incentive scheme would be more motivating than an individual incentive scheme. In reverse, we expect that for pickers with a dominant promotion focus the independent aspects of dynamic zone picking would be highly salient and consequently that an individual incentive scheme would be more motivating than a group incentive scheme. This leads to Hypothesis 5.

Hypothesis 5: In dynamic zone picking, promotion-focused pickers will perform substantially better with an individual-based incentive system than with a team-based incentive system, whereas prevention-focused pickers will perform substantially better with a team-based incentive system than with an individual-based incentive system.

3 Methodology

3.1 Participants and Location

The hypotheses were tested using data obtained from an experiment with 182 participants arranged into 48 four-person teams. In each team, one person was assigned the role of quality inspector. The three others were order pickers, the main research subjects of this experiment. The role of quality inspector was performed by a confederate of the experimenter in 8 teams.

The experiment took place in an experimental warehouse setup (Figure 1). This warehouse was especially erected with the support of several material handling suppliers, supplying racks, picking carts, labels, dummy products, and a WMS system. The 1000 colored and labeled wooden dummy products ranging in volume from 0.2 to 2 liters and in weight from 50g to 500g were placed at two sides of two (identical) warehouse aisles. The two identical aisles allowed us to execute two simultaneous experimental sessions.

Figure 1: Experimental warehouse layout (measures are in meters).

3.2 Manipulations & Measures

The experiment used a 3×2 between-subjects design, with picking method and incentive condition as independent variables. Picker teams were randomly assigned to a picking method and incentive condition.

Picking methods: We used three paper picking methods: 47 participants used parallel picking, 47 used (pick and pass) zone picking, and 48 employed dynamic zone (bucket brigade) picking. The zones used for zone picking are shown in Figure 1, with section 1-3 as part of zone one, section 4-7 as part of zone two and section 8-10 as part of zone three. The zones were delimited by a table that served as a buffer. Since the ten

sections could not be equally divided among three order pickers, order picker two had a slightly larger zone in this setup. We controlled for this in the analyses.

Motivational incentives: Sixty-nine participants (distributed across the three methods), had to complete as many errorless orders as possible in a team (team-based incentive system), whereas the other 73 participants had to complete as many errorless orders as possible individually (individual-based incentive system). In both conditions, the winners received a €100 voucher for a large electronics & media retailer.

Productivity was measured by counting the amount of completed order lines per individual during the real picking run of 10 minutes, ensuring that the pickers had already become familiar with the method in the practice round.

Quality was measured by the percentage of orders per individual that contained errors during the real picking round.

Promotion focus (α=.798) and *prevention focus* (α=.849) were measured using Wallace and Chen's (2006) Regulatory Focus at Work Scale in the first questionnaire that the participants completed.

Age, education, and *experience* with order picking of the participants were measured in the first questionnaire to be used as control variables. *Age* was measured in years, *experience* with order picking was measured in months, and *education* was measured by respondents indicating their highest completed level of five possible options: primary school, high school, vocational college, polytechnic institute or university. We also introduced a dummy variable indicating whether a participant was the second or third order picker in the zone or dynamic zone picking method. This was done to control for the different picking situations of the second and third picker, who are, to a certain extent, dependent on the first picker in these methods.

4 Analyses and Results

Productivity: Before adding the control and independent variables to a model predicting productivity, we compared a model without a random intercept with one that contained a random, group dependent intercept. These models were fit using the 'lme' and the 'gls' functions in the 'nlme' package [37] in R 3.0.1 [38]. The -2 log likelihood value for the random intercept model (996.45) appeared significantly larger than the value for the model without the random intercept (986.59, $\Delta = 9.86$, $p < .01$), indicating a significantly better fit for the random intercept model. Subsequently, we created a linear mixed-effects model with a random intercept and participant background, age, education, and order picking experience as control variables. Furthermore, we controlled for the position of the pickers in a zone or dynamic zone picking method. In the first model, the picking method was added to the control variables as predictor. The effect of the picking method on the number of lines picked was significant (Wald $\chi^2 = 7.68$, $p < .05$), which indicates that the employed picking method significantly influences the number of lines picked.

To find out whether an individual or a team-based incentive system leads to optimal picking performance, we added the incentive condition and its interaction with the picking method as predictors. The interaction effect proved significant (Wald χ^2 (1,

109) = 6.65, $p < .05$). Visualization of the interaction effect (Figure 2) and pairwise comparisons of the least-squares means [39] showed that an individual-based incentive system yielded substantially more productivity in the parallel picking method (M = 53.9, SD = 3.38) than a team-based incentive system (M = 46.84, SD = 4.52). In contrast, a team-based incentive system performed better in a zone picking method (M = 47.58, SD = 3.90) compared to an individual-based incentive system (M = 35.37, SD = 3.41). Hardly any differences between an individual-based (M = 41.03, SD = 3.41) and team-based (M = 43.91, SD = 3.50) incentive system emerged for dynamic zone picking. These results are exactly in line with our first and second hypothesis regarding productivity.

The dominant regulatory focus, which indicates whether a participant is mainly prevention-focused or promotion-focused was added, predicting productivity in a three-way interaction to find out how regulatory focus interacts with the picking method and incentive condition. This interaction proved marginally significant (Wald χ^2 = 5.09, $p = .078$). Inspection of the three-way interaction plots (Figure 3) reveals that participants with a dominant prevention focus consistently scored slightly higher with a team-based incentive system, regardless of the picking method. In contrast, participants with a dominant promotion focus performed better in parallel picking with an individual-based incentive system and better in zone picking with a team-based incentive system. No differences could be observed for a dynamic zone picking method. These results are not completely in line with hypotheses 3, 4, and 5. Instead, the results suggest that pickers with a dominant promotion focus are more sensitive to the fit between the picking method and incentive system than pickers with a dominant prevention focus; a parallel picking method fits particularly well with an individual incentive system, whereas a zone picking method fits well with a team incentive system. A dynamic zone setup can be considered a combination of the other two methods, which is reflected by the similar performance in individual-based and team-based incentive conditions.
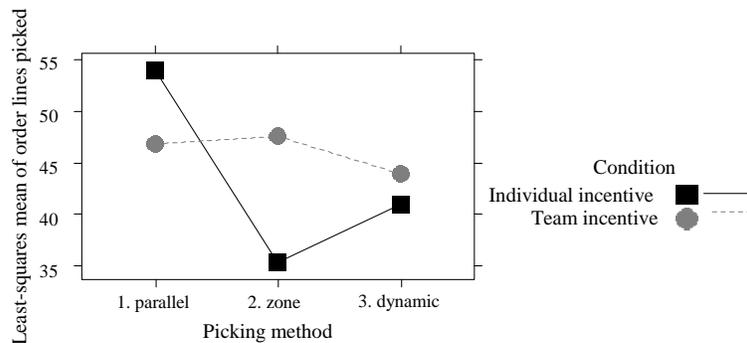

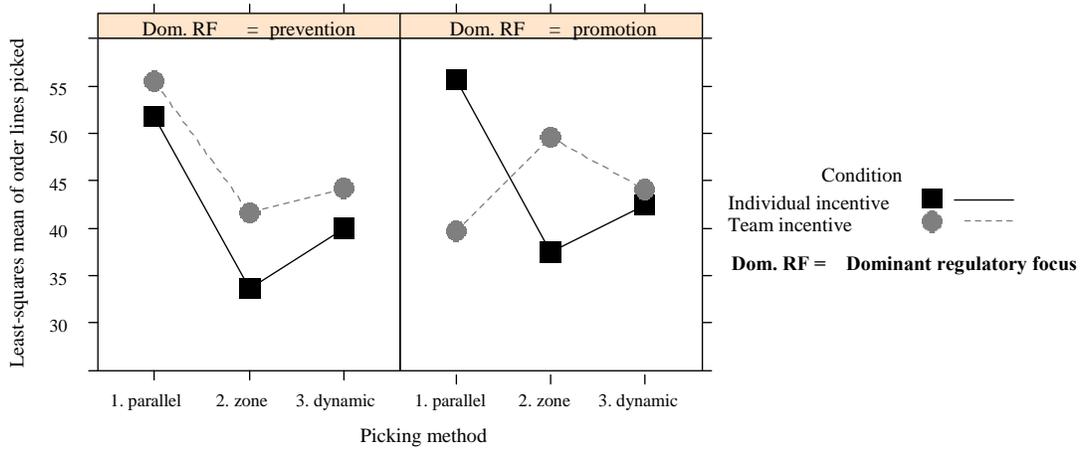Figure 2: Interaction between picking method and incentive condition on productivity.

Figure 3: Three-way interaction between picking method, incentive
condition and dominant regulatory focus on productivity.

Quality: With the number of orders with errors as dependent variable, the difference in -2 log likelihood value between the random intercept model (10.14) and the model without random intercept (9.68) was not significant (Δ = 0.47, *p* = .49), which indicates that adding random intercepts did not significantly improve the model. Therefore, we performed a one-way ANCOVA with method as factor and the same set of control variables as in the model that predicted productivity. No significant main effect of method could be identified, and the model explained only 6.1% of the variance in errors. However, the interaction between picking method and incentive condition also proved to be significant for quality (F(96) = 3.25, *p* < .05). The plot of the interaction effect (Figure 4) and the least-squares means show that the percentage of orders with errors is lower for an individual-based incentive system than for a team-based incentive system in a parallel (M = 18.3%, SD = 5.7% vs. M = 23.2%, SD = 7.3%) and zone picking method (M = 19.1%, SD = 5.3% vs. M = 31.6%, SD = 6.5%), but higher in a dynamic zone picking method (M = 29.6%, SD = 5.9% vs. M = 14.4%, SD = 5.6%). Even though we hypothesized that a zone picking system in combination with a team-based incentive system would result in fewer errors (Hypothesis 2), the opposite appears to be the case. The results suggest that people generally work more accurately when motivated by an individual-based incentive system, but that such a system is detrimental if workers have to coordinate the distribution of tasks, which essentially happens in a dynamic zone picking method. There was no significant three-way interaction between the dominant regulatory focus of participants and the picking method or incentive condition, which implies hypotheses 3, 4, and 5 do not hold for quality as performance measure.
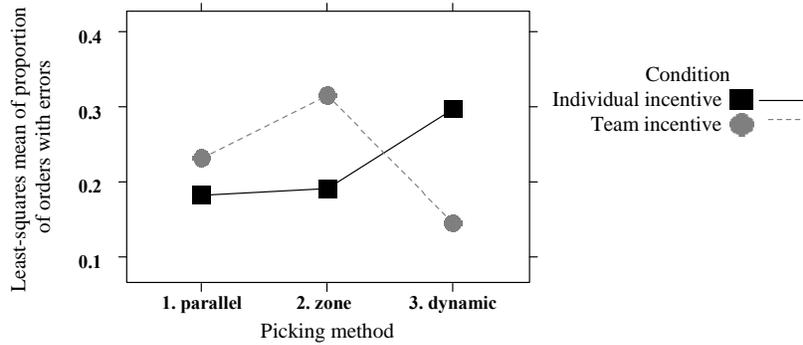
Figure 4: Interaction between picking method and incentive condition on quality.

Job satisfaction: We employed the same type of analysis for job satisfaction as we did for quality, but without testing for group-level effects. A first model with all control variables and the picking method as predictors revealed a nearly significant effect of method. This model explained 13.9% of the variance in job satisfaction. The results indicated that the job satisfaction for parallel picking is higher than for the other methods, but pairwise comparisons show that only the difference between parallel (least-squares mean = .30, std. dev. = .18) and dynamic zone picking (least-squares mean = -.56, std. dev. = .15) is significant (*p* one-tailed = .035). We found no interaction between picking method and incentive condition for job satisfaction, and dominant regulatory focus dominance did not appear to play role. These results suggest that the particular combination of method, incentive system, and regulatory focus of the picker does not influence job satisfaction.

Not only the statistical analyses and absolute numbers, but especially the effect sizes of the behavioral factors illustrate the impact that a change of incentive system or type of employee can have on productivity, quality, and job satisfaction in practice. Table 1 provides an example of the performance improvements in a given picking method (zone picking) if the incentive system is changed or if pickers with a different dominant regulatory focus are deployed. Both above and below the dotted lines, the combination of method, incentive system, and possibly regulatory focus with the lowest performance in the particular performance measure is used as a baseline and is assigned a score of 100. Regarding quality, the highest number of errors is considered the lowest performance. The scores of the other combinations reveal their performance compared to the baseline.

Table 1: Comparison of effect sizes for zone picking (Baseline = 100).

Zone picking	Picked lines	Errors	Job satisfaction
Team-based incentive	134.3	**100**	**100**
Individual-based incentive	**100**	60.7	103.8
Team-based incentive, prom. dominance	147.5	33.8	103.1
Team-based incentive, prev. dominance	123.9	**100**	102.4
Individual-based incentive, prom. dominance	111.5	12.2	**100**
Individual-based incentive, prev. dominance	**100**	40	110.0

In zone picking, the switch from an individual-based incentive system to a team-based incentive system leads to 34.3% productivity gains on average. However, also the number of errors increases by 39.3 percentage points (Table 1). If regulatory focus is taken into account as well, productivity could increase by up to 47.5% whereas errors could simultaneously be reduced by up to 66.2 percentage points. The differences in job satisfaction are small, except for the 10% difference between pickers with a dominant prevention focus and a dominant promotion focus working with an individual-based incentive system.

5 Conclusion

Through this experiment, we found that aligning the right incentive system with the right picking method can lead to increased productivity and quality. In particular, parallel picking works best in combination with an individual-based incentive system (Hypothesis 1), whereas zone picking performs optimally with a team-based incentive system (Hypothesis 2). For dynamic zone picking, the difference between the two incentive systems was negligible. This result neatly confirms the theory that individualized incentive schemes are more effective when the task is more independent (such as parallel order picking), whereas team-based incentive schemes are more effective if the task requires interdependent operation. Furthermore, the results that show the influence of the combination of regulatory focus, method, and incentive system on productivity are novel. The difference between the two incentive systems was indeed the largest for people with a dominant promotion focus in parallel picking (Hypothesis 3), and for people with a dominant prevention focus in zone picking (Hypothesis 4). In dynamic zone picking, people with a dominant promotion or dominant prevention focus performed similarly (Hypothesis 5). The performance improvement realized by optimally combining these factors illustrates the impact that regulatory focus and incentive systems can have in addition to the choice of a picking method. This is most likely not only relevant to the context of order picking, but could be applicable to all types of repetitive labor. Investigating this in a different context while possibly taking other behavioral factors into account could be interesting in this respect.

For most companies, the potential positive effects of implementing an incentive system in general are probably no surprise. However, the best type of incentive and the magnitude of the effects of the choice between incentive systems might be not so well known. Implementing the findings of this study in practice requires incentives that can be realistically made part of the company's reward structure. For individual incentives, an example of this is employing piece-rate pay in addition to a base wage. In our situation, this could be paying employees an additional amount per completed pick or order (a statistic registered by many warehouses already). Something similar could be implemented at the team level, in which case the additional amount is based on the team performance. It should be noted that also non-monetary incentives, such as small prizes or privileges, can be effective [40]. Furthermore, as many warehouses use multiple picking methods in different parts of the facility (De Koster et al., 2007), companies might try to assign people with a particular regulatory focus to the right type of picking

process, or even use regulatory focus as one of the selection criteria in the hiring process. As we have found, people with a dominant promotion focus are more productive in a parallel picking method with an individual-based incentive system, whereas people with a dominant prevention focus are more productive in a zone picking method with a team-based incentive system. To make use of this, companies can re-assign employees with a particular dispositional regulatory focus to tasks that are better aligned with their regulatory focus.

Aligning regulatory focus, incentive systems, and order picking methods helps to close the gap that exists between operations management theories and their applicability to practical settings. The use of a controlled field-experiment which included both professional order pickers and students as participants has enabled us to obtain results that are generalizable to practice without compromising on scholarly rigor.

Acknowledgements

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