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Happier and further by going together: The importance of software team behaviour during the COVID-19 pandemic

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ABSTRACT

The COVID-19 pandemic, and the associated move to remote work and the resulting changes to the normal work routine, have introduced a plethora of new difficulties and challenges for software developers. Recent research has focused on the impact of the COVID-19 pandemic on the developer's wellness, productivity, team collaboration, job satisfaction, and work-life balance. However, research exploring the association between these feelings and team behaviour during such a crisis period has not been previously developed. Moreover, previous research has indicated that organisations are still struggling to understand the pandemic and its relationship with both team behaviour and developer feelings. To address this gap, we analysed how COVID-19 influences a developer's happiness and their feelings of (un)happiness associated with the team's behaviour during the COVID-19 pandemic. A state-of-the-art analysis helped to design a scale that we used in a cross-sectional study of 102 software developers. To test the proposed hypotheses, we conducted exploratory factor analysis and principal component analysis. Our results highlight that happiness positively influences a team's behaviour and that unhappiness negatively affects their work results and productivity. These findings provide software companies and organisations with a better understanding of the importance of team behaviour on individual happiness during crises. These results provide information that managers and companies can use to mitigate potentially negative effects.

1. Introduction

The World Health Organization (WHO) declared the spread of the new SARS-CoV-2 [1], also known as COVID-19, as a public health emergency of international interest [2] on January 30, 2020. The virus was first identified in patients with pneumonia in Wuhan, Hubei Province, China, in December 2019 [3]. Due to its high transmission rate, the virus has gained a prominent focus in the world scientific community [3]. The COVID-19 pandemic has caused unprecedented challenges to public health systems and global economies [1,3–5]. Governments have implemented social distancing to contain the virus. The COVID-19 pandemic has had a significant impact on all companies, with strict physical distance requirements maintained in many countries worldwide. This includes software developers¹ who do not work with distributed teams. Moreover, for developers who have been working

remotely, working from home during a pandemic is not like regular remote work. Further difficulties arise due to a variety of factors, including the lack of proper physical infrastructure, the need to care for children as schools and daycares closed, and fear or anxiety of contracting COVID-19 [6,7].

Several surveys have assessed the impact of the COVID-19 pandemic on software developers, such as on measuring practitioner wellness [8], individual productivity [9], team productivity [10], team collaboration [11], and job satisfaction and work-life balance [12]. Ford et al. [13] noted the dichotomy of the same factors can have negative and positive effects. For example, NicCanna et al. [14] observed that people working remotely missed social interactions, found it difficult to create a clear boundary between their home life and work, suffered from poor ergonomics, had less visibility and awareness of how other people in their company were working, and exercised less. Communication was also an

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¹ Software developers are considered professionals who work with any aspect of software building, including design, management, planning, development, and testing software solutions for different purposes, including work, hobby, or passion [15].

issue, and some employees who are parents suffered additionally from a lack of childcare. Additionally, research [8,13] has indicated that organisations and software developers are still struggling to understand the pandemic and how it has affected team behaviour and to understand the relationship between employees' happiness and this behaviour. Moreover, there is a gap in the literature regarding associations between these feelings and team behaviour during a crisis period, such as the COVID-19 pandemic.

The most significant consequences of happiness for the developer's well-being are higher cognitive performance, higher motivation, perceived positive atmosphere, higher self-accomplishment, higher work engagement and perseverance, higher creativity, and higher self-confidence [15]. Creativity is also important for work in environments that are constantly innovating, as is the case for software developers [16]. According to Brey [17], the key aspects of well-being are debated and may vary from person to person, but generally involve physical health, autonomy, and self-confidence. Higher self-confidence refers to a greater trust in one's own abilities. This category includes both higher general self-confidence and task-specific self-confidence (i.e., self-efficacy) [15].

Previous research has also documented the negative impacts of working from home on personal well-being. Among them, the blurred boundary between home and work can result in problems, such as the "always-on culture", which is facilitated by information and communication technologies (ICT) and makes it difficult for knowledge workers to switch off, which results in work intensification [7,18]. Moreover, it brings distractions from the home environment and family members [19]. Mazmanian et al. [20] argued that the increased use of technology results in an "autonomy paradox": although ICT offers more flexibility for work and living arrangements, it also imposes pressure on knowledge workers regarding constant connectivity and responsiveness [21].

In the current scenario, wherein software developers are strategic assets for the software companies at which they work, there is a need for research on how the COVID-19 pandemic has influenced the happiness of software developers. Specifically, in the present study, the question of primary interest is: *How were developers' feelings of happiness or unhappiness associated with their team's behaviour during the first wave of the COVID-19 pandemic?* To answer this question, we designed and surveyed software developers to collect their responses on this topic. We used responses at the individual level to investigate how COVID-19 has affected the happiness of different software developers, which allowed us to assess possible inequalities in the distribution of the mental and physical health consequences of COVID-19.

The pandemic is reshaping how companies work, including software engineering companies, and is generating changes in the processes, methods, and collaboration tools used to work. In this study, we hypothesised that feelings of happiness and unhappiness affect developers during the pandemic, and that these feelings impacted the behaviour of the teams in which they work. We report the results of our investigation of how feelings of happiness affected developers during the pandemic's first wave in Brazil, and how these feelings impacted their team's behaviour.

Overall, our analysis highlights that happiness positively influences a team's behaviour and that unhappiness negatively affects work results and productivity. The findings of this study can inform software developers of the importance of team behaviour to individual happiness during crises. Moreover, it contributes to the understanding of the emotions associated with software development and their impacts.

The remainder of this paper is organised as follows: In Section 2, we introduce the background to the problem and define our hypotheses. Section 3 describes the proposed method. Sections 4 and 5 present the results, their implications, and limitations. Finally, in Section 6, we state the threats to the validity of this study, and Section 7 presents the conclusions and future research directions.

2. Background and related work

This section briefly reviews two key concepts: happiness and unhappiness in software engineers and team behaviours. This is followed by a discussion of related works, and finally, the research model is presented, as well as the research hypotheses.

2.1. (Un)Happiness in software engineers

Zelenski et al. [22] suggested that happy people are more productive. According to a study conducted by Diener et al., happy software engineers have more positive experiences than negative experiences [23], and unhappy software engineers experience more negative than positive experiences. Thus, to achieve better productivity results and better team performance, organisations within the information technology (IT) environment should aim to maximise happiness among their employees. This can be achieved by maximising positive experiences, minimising negative experiences, or both [15,24]. Thus, the happiness of all stakeholders involved in software development is an essential element of company success [25].

Happy software developers solve problems better [26,27] and, according to Ford and Parnin [28], positive feelings are perceived to enhance developer productivity. In contrast, the negative affect most prevalently perceived among software developers is frustration, which is also the emotion that is perceived to reduce productivity the most.

A recent review [29], has indicated that research on emotions in the field of software engineering has increased in recent years, although this research field is not yet mature. The authors conducted a systematic literature review of software developers' emotions in software engineering. Nevertheless, independent of work field, it has long been established that human performance and decision-making are affected by external factors, such as stress [30,31]. Moreover, the ability to make decisions that affect the quality of the work is strongly associated with the work being exciting and challenging, as well as with job satisfaction [30]. However, Zelenski et al. [22] also noted that these are not the only factors linked to a happy person.

A growing body of literature has studied how these feelings are linked to happiness and performance, specifically examining the effects of when employees are feeling collaborative and satisfied [15,30,32], motivated [32,33], communicative [34,35], engaged [15], collaborative [34], and joyful and positive [23].

França et al. [32,36] observed that happy software engineers are ones who are satisfied. According to Feldt et al. [30], this satisfaction is associated with the ability of the developers to make decisions and with the level of challenge found within the work environment. In this sense, França et al. [32] reported that job satisfaction affects physical and mental health, which is consistent with Zelenski et al. [22] and associates factors like these to greater productivity and better performance.

Previous research by Graziotin et al. identified that working on mundane or repetitive tasks is a process-related factor that often causes negative feelings in developers [37]. The words used to describe what about the job made them unhappy included "Boredom", "boring", "dull", "monotonous", "trivial", "recurrent", were words that developers used to describe the tasks that made them unhappy [37]. This is relevant, because emotions involve different elements [38]. Previous research has suggested that the negative emotions and moods related to unhappiness include frustration [13], low motivation [15], anxiety, poor communication, anger [13], insecurity, and boredom. Indicators such as those help us understand and measure who could be considered happy or unhappy, which can then be related to their work performance and its impact on the team's goals.

2.2. Team behaviours

Existing literature has described the relationship and impact of several emotions on team behaviour, including happiness. Moreover,

these behaviours are often associated with team productivity and performance. This section presents research related to team behaviours.

Amorim et al. [39] identified that team members with a higher happiness index tend to be more collaborative. In addition, the authors also confirmed the influence of good communication on team members' happiness and the resulting good performance of those teams. Fagerholm et al. [35] identified that there is an intrinsic relationship between the ease of communication within the teams and the happiness or unhappiness of the members, and that creating a communicative atmosphere is beneficial for the performance of individuals.

According to Johnson et al. [40], as the distance between team members increases, and the amount of face-to-face communication decreases, all forms of communication and collaboration also decrease. These are the biggest challenges for software teams, wherein virtual space applications have been used as an attempt to alleviate these communication problems. Unfortunately, in the face of the pandemic, these practices have needed to be adapted. Remote communication has even more challenges which impact the productivity of software companies [41]. Johnson et al. [40] researched robust tools that could be used to facilitate remote communication (e.g., video conferencing meetings, chat applications, file sharing). As presented in Camara et al. [42], software start-ups can modify their agile methodologies from being co-located to remote due to the pandemic. This was corroborated by NicCanna et al. [14], who reported that modifying the practices adopted in the organisation with projects globally distributed to allow working from home.

In previous research [43], autonomy was defined as a feeling of independence, freedom, and control (or self-determination). According to Guzzo and Dickson [44], an autonomous team receives "significant authority and responsibility for many aspects of its work, such as planning, scheduling and assigning tasks to members, and making decisions with economic consequences".

According to Rego et al. [45], employees with more positive perceptions of team spirit showed higher effective well-being. According to the authors, the spirit of camaraderie can be defined as the degree to which interpersonal relationships in the organisation are characterised by friendship, team spirit, and mutual concern. Van Kelle et al. [34] stated that most of work-related projects do not fail because of technology, but rather due to social and organisational problems, a lack of practical communication, and misalignment in team goals and attitudes. Moreover, a better understanding and appreciation of other team members' contributions increases team spirit and enjoyment.

The success of software management and development does not depend only on technologies, but also on human decisions about what should be done in the process [30]. Moreover, higher creativity has also been reported as a result of happiness [15], and broadened cognitive processing can be triggered by happiness [46]. Thus, the inclusion of team members in a team's decision-making process appears to have a positive impact on the members' motivation and performance [39].

Van Kelle et al. [34] identified the impact of transformational leadership on the results of agile projects. Transformational leadership is defined as an adaptive leadership style that revolves around motivating, inspiring, expressing visions, and engaging the emotional involvement of followers, while focusing on long-term commitment and engagement. Therefore, according to Van Kelle et al. [34], having a transformational leader who brings the best from everyone in a team is the decisive key to develop individuals who are more engaged, satisfied, and committed to deliver the best results.

Moreover, positive work engagement is known to produce positive individuals, teams, and organisational outcomes. Engagement refers to a more continual and pervasive affective-cognitive state that is not focused on any specific object, individual, event, or behaviour [47]. It is crucial that individuals feel encouraged to work with their teammates in a software development context. Such behaviour is referred to as work engagement, a state in which a person feels that they are able to work at their job in a fully energetic, enthusiastic, and immersed way [48].

Being engaged leads individuals to increase their physical, cognitive, and emotional presence at the workplace, which leads the team to achieve its full performance [48]. Work engagement is thus a factor for increasing job and organisational performance. It also helps to improve organisational results, as well as to improve creativity and innovation [49]. Furthermore, work engagement is a critical indicator of well-being at work, which is also related to job satisfaction [49].

One of the consequences of happiness is the higher learning abilities that teams acquire. Once teams are happy and embedded in a positive atmosphere, it is possible to improve and promote team learning and encourage individual team members to learn and develop new skills and techniques [15].

Additionally, previous research [15] identified importance of having a challenging environment in which the developers are experiencing happiness. One such developer reported that executing challenging tasks while he was happy and experiencing positive feelings made him exceed his expectations of his own performance [15]. This is only possible in balanced, challenging environments that promote challenging tasks to encourage developers. One of the consequences of happy teams and challenging environments is the high code quality that these teams can produce [15].

Fagerholm et al. [35] described how managers can become aware of, interpret, and adjust their team's performance. To maintain high-performing teams, it is necessary to be able to adapt during the software development lifecycle. The concepts of alignment and performance work together, creating strong and effective bonds with the team to achieve better performance and alignment levels [35]. Moreover, performance can be regarded as a continuous process of negotiation and alignment within teams and with external stakeholders [35].

Grazziotin et al. [15] observed that the lack of a defined process during software development can lead to many unhappy consequences, including low productivity. The more unhappy teams are, the more the tasks they are working on will be delayed in their delivery, the more miscommunications could arise, and the greater likelihood that deadlines could be missed [15]. The study also identified that unhappiness decreased process adherence, which led developers to build inadequate solutions just to get rid of the job quickly [15]. However, in contrast, happy teams usually show more adherence to the software development process, promoting their members to follow code standards, write more tests, and work on documentation.

According to Yu-Cheng [50], transparency in the workplace context refers to the act of making information visible or accessible to people. This is important in software design, as by facilitating communication, the organisation can remove barriers to performance [35], enhance performance experiences that require communication, and boost team spirit and team identity during the development process.

2.3. Related works and hypothesis

Sánchez-Gordón and Colomo-Palacios [29] conducted a survey study to identify the emotions of software practitioners during presentations and coding activities. The survey was conducted with 47 students, and the authors used the Discrete Emotions Questionnaire [29] to identify the rating of eight distinct emotions: anger, disgust, fear, anxiety, sadness, happiness, relaxation, and desire. The authors found that anxiety, happiness, and fear were the emotions most associated with presentation tasks, whereas happiness, relaxation, and anger were the emotions most associated with coding tasks. These results demonstrate that even though a task (i.e., presentations) can generate fear and anxiety, it can also result in happiness when the task goes well. Similarly, although coding can provide happiness and relaxation, it can cause anger due to challenges that arise during the coding task. This study represented a strong initial investigation on the topic, however because it was conducted with only 47 students, there is the possibility that it is not representative of the broader population. By employing a broader approach, we aimed to conduct a similar study based on a larger sample

of 102 software practitioners in the industry. In this survey, we evaluated the participants' feelings during the COVID-19 pandemic while working on software projects remotely.

Another recent study similar to ours was published by Bezerra et al. [10]. They investigated how several environmental factors impacted software development teams' productivity during the COVID-19 pandemic. For data collection, a survey was conducted with 58 respondents from Brazilian software companies. Their results indicated that most respondents (74.1%) considered themselves to have good to excellent productivity, although most reported suffering from external interruptions, adaptation issues, and emotional matters. Additionally, a key factor presented in the survey was that good productivity was related to a skilled, experienced, and collaborative team. Furthermore, only 67.2% of the participants had a specifically reserved work environment at home, and 46.6% said they did not receive any assistance from their companies to work remotely. In our study, we present the results of an in-depth investigation of one of the aspects ("happiness") observed by the authors as related to the emotional aspects. Moreover, we investigated one of the aspects that Bezerra et al. [10] identified as having the most significant impact on productivity. Finally, we thoroughly examine *how* these emotions influence productivity, not simply *which* feelings were felt during social isolation.

Amorim et al. [39] recently conducted a survey that examined how happiness and unhappiness impacts software engineers in agile teams. Their results showed that younger software engineers (i.e., those just beginning their careers) tended to suffer more from anxiety and frustration, which negatively impacted their performance in the software development process. Additionally, the authors identified happiness factors that impacted software engineers in agile environment, including motivated members, leaders who were present, collaboration among members, effective communication, and proactive members. Moreover, the authors observed that professional recognition from leaders was a key to encouraging happiness within an agile team. However, according to DiGiovanni [51], people are less likely to comply with team requirements when they are facing potential losses of income, personal logistical problems (e.g., how to get groceries), isolation, or psychological stress (e.g., fear, boredom, frustration, stigma). Moreover, individuals attempting to minimise their stressful situations will often use some form of coping mechanism [52]. Therefore, although previous research has also focused on happiness, in the present study we also considered the context of social isolation and the losses faced during the COVID-19 pandemic.

Bao et al. [9] collected data from a Chinese company, which included 139 developers working on eight projects over 138 business days and

compared the productivity of the developers when working at home and on-site. They found that working from home differentially impacted different types of projects. For example, working from home negatively affected developer productivity for large projects. They also found that the productivity of most developers was similar when working from home as when working on site.

Based on the research summarized above, we generated the following hypotheses. These hypotheses were generated contemporaneously with a questionnaire design before data collection began. We tested the hypothesis that there is a significant association between an individual's feelings and team behaviours in software companies during the COVID-19 pandemic. Our study tested the following hypotheses:

- H1: there is a positive association between happiness and team behaviours;
- H2: there is a negative association between unhappiness and team behaviours;
- H3: there is a negative association between happiness and unhappiness.

The conceptual model is described in Fig. 1.

3. Method

3.1. Study design

We conducted a cross-sectional study with voluntary participants of both genders. To conduct the survey, we initially performed an exploratory review. The exploratory review aimed to identify and classify the relevant feelings and team behaviours to build the scale which would then be used in data collection. We mapped the 20 most frequent feelings (ten positive and ten negative) that impacted software developers, along with 13 consequences of these feelings in team behaviours. We also evaluated the Scale of Positive and Negative Experiences (SPANE) from Diener [23]. In SPANE, Diener [23] described 12 feelings associated with human experience: six positive and six negative.

Based on the review, the data from the literature review were labelled through qualitative coding (open coding) [53] to identify similarities and sort them according to the constructs related to happiness/unhappiness and team behaviours. Thus, we extracted from the literature a set of feelings related to happiness, unhappiness, and a set of behaviours related to the team. These feelings and behaviours are shown in Table 1.

A web survey using Likert-scale questionnaires and demographic information collection was distributed to the target population (see

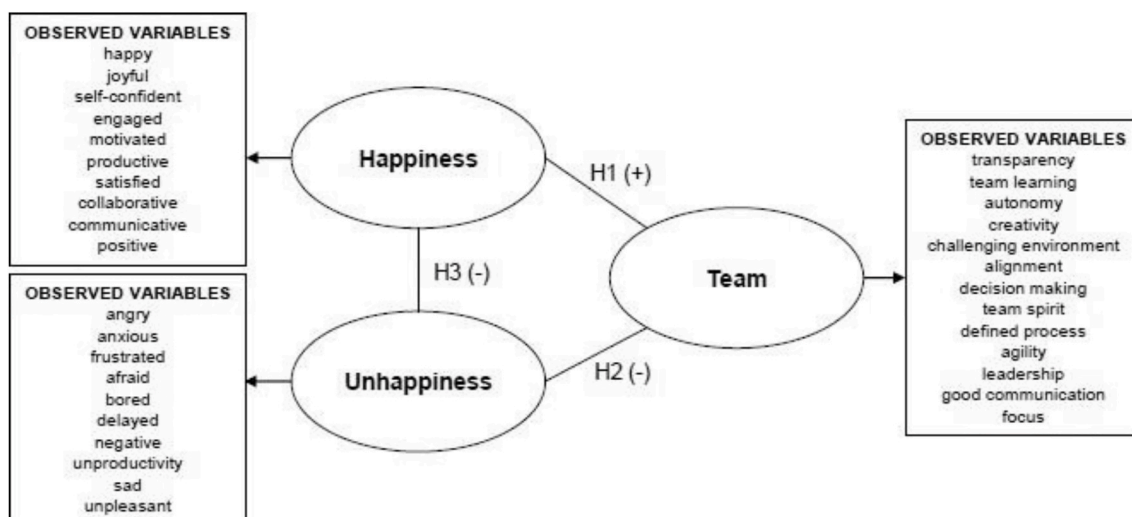


Fig. 1. A conceptual model of Un(Happiness) in Software Development.

Table 1
Feelings related to happiness, unhappiness, and behaviours related to the team.

Happiness		Unhappiness		Team behaviours	
Feelings	References	Feelings	References	Behaviours	References
Happy	[23]	Anger	[23]	Transparency	[50]
Joyful	[23]	Anxious	[37,54,54]	Team learning	[15]
Self-confidence	[15,23]	Frustrated	[15,28,37]	Autonomy	[43,44]
Engaged	[15,35]	Afraid	[23]	Creativity	[15,26,36]
Motivated	[15,32,33,36]	Bored	[23]	Challenging Environment	[15]
Productive	[15,24,27,36,55]	Delayed	[15,54]	Alignment	[35]
Satisfied	[22,36,56]	Negative	[23]	Team spirit	[45]
Collaborative	[35,36]	Unproductive	[15,24,54,57]	Defined process	[15,30,46]
Communicative	[35,39]	Sad	[23]	Agility	[54]
Positive	[23]	Unpleasant	[23]	Leadership	[34]
				Good Communication	[34]
				Focus	[36]
				Decision Making	[30,39]

Appendix A). Each participant evaluated their emotions during the coronavirus pandemic and how these emotions may have affected their respective teams. We used a Likert scale from 1 to 5 for each item, with one corresponding to Never, and five corresponding to Always.

Our research was designed to illuminate how happy or unhappy software developers were as a result of the COVID-19 pandemic. We chose a web-based survey because it: (i) is suitable for collecting information quickly from a large audience, (ii) requires a modest development effort, and (iii) can produce quantitative data.

3.2. Setting

Our research aims to study software practitioners that operate in at least one agile project of any company from Porto Digital (Recife, Brazil) [58]. Porto Digital is one of the principal technological centres and innovation environments in Brazil [59]. Located in Recife, it operates in the software and services of information and communication technology (ICT) and creative economics (CE), emphasising the development of software, games, cine-video-animation, and design. Porto Digital derives from the coordinated action between the government, academia, and companies, in what is known as the Triple Helix model. This initiative provided the necessary conditions to make Porto Digital one of the leading innovation environments in the country. It employs approximately 11,000 workers with annual revenues of BRL 2.3 billion in 2019. Moreover, this work strategy was not common prior to the pandemic. Indeed, the law was adjusted to allow for this kind of work. Therefore, after data collection, we contacted 21 companies to question the administration about this modality of work. Before the pandemic, only large companies had employees working remotely, and then it was only 1.5%–2% of their team. The majority of companies did not use this modality of work.

3.3. Participants

We calculated the sample size based on Cochran [60] using the population of 9000 employees [58]. The population standard deviation was estimated using a sample standard deviation of 1.1. The absolute tolerable error was 20% of the standard deviation (0.22), with a 95% confidence interval. The minimum sample size was 96 participants. Thus, our study involved 102 software developers. We followed Graziotin's [15] operational definitions, wherein a software developer refers to anyone concerned with any aspect of the software construction process (including but not limited to research, analysis, design, programming, testing, and management activities) for any purpose, such as work, hobby, or passion. The following roles participated in the research: requirements engineer, security analyst, developer, project manager, project leader, scrum master, tester, and UX/UI analyst. These practitioners maintained their activities during the COVID-19 pandemic.

3.4. Survey design

In this study, we used a web survey method to gather data. We distributed to the target population a web-based survey with a Likert scale divided into four sections. First, we presented basic questions to assess the participant's view of how the COVID-19 pandemic impacted their level of happiness. The second section examined their perception of happiness or unhappiness. We used these results to analyse each individual's (un)happiness during the pandemic period using a 5-point Likert scale. The third section concerned the team, to assess the individual's relationship with their team. Lastly, participants were categorised according to sex, age, role or position, time of experience, education, project, and company type.

To test content validity and readability, we performed a pilot survey with 67 software engineers. The Porto Digital members supplied feedback to improve the research. The pilot survey allowed us to estimate and improve response rates by refining the questions and invitation emails. We did not use any information from the first dataset, and pilot participants did not participate in the final round. The final questionnaire was then distributed electronically from June to September 2020.

Our research used Google Forms to implement the survey, which included a web link to a consent form to participate in the survey. The first question in the survey provided a clickable checkbox by which subjects had to indicate that they had read the informed consent form and consented to our use of their responses to the study.

We used non-probabilistic convenience sampling with self-selection. We advertised the survey on electronic mailing lists and social media oriented to the Porto Digital community. Recipients were free to participate on a voluntary basis. The introduction and instructions for the survey were brief. The survey had a final closing date of September 18th, 2020.

3.5. Data analysis procedure

We performed a scale refinement process, as described in the literature [61], through intra-item correlations and exploratory factor analysis. Then, a confirmatory component analysis was performed to test the hypotheses.

The data analysis procedure was divided into four stages. First, we used a frequency distribution to define the sample profile based on socio-demographic indicators. From this, the team's midpoints on the happiness and behaviour scales were established.

Then, we began the scale preliminary validation procedure by applying the Kolmogorov-Smirnov (KS) and Shapiro-Wilk tests to verify data normality. We assessed the reliability of the scale using Cronbach's alpha coefficients and composite reliability. As recommended by Hair et al. [61], the values must be above the reference value of 0.7, even though values between 0.6 and 0.7 are considered satisfactory.

Therefore, the internal consistency and adequacy of the scales were demonstrated.

The next step was to refine the scale to better understand the constructs. Constructs (or latent variables) are phenomena of theoretical interest observed by indirect manifestations, which are themselves referred to as measures or items. In this context, a measurement model describes the relationships between the construct and its measures (items).

Intra-scale Spearman correlation tests were performed and, when necessary, items that did not show significant scores were removed. By considering reflective measures as interchangeable, removing one does not alter the meaning or interpretation of the construct.

After analysing the internal correlations, we proceeded with the exploratory factor analysis (EFA), using the Varimax rotation method implemented in the SPSS® 23 software support, to clarify the items' factorial load patterns for each factor. For the sample size (n = 102), loads above 0.55 were considered, as recommended by Hair et al. [61]. The EFA assumes that there is an unobserved construct that causes correlations between items. Based on the structure presented from the EFA, we performed principal component analysis (PCA), which seeks to compose a new variable with the complete pertinent information from the set of indicators. We conducted our PCA with the Smart PLS® software. During this phase of analysis, we observed the convergent and discriminant validity. Convergent validity assesses the degree to which two or more measures are correlated with the same construct. In turn,

discriminative validity demonstrates the degree to which one construct is different from others based on the measures that form each construct [61].

To test the hypotheses, after the scale refinement process we analysed the correlation between the constructs. We evaluated the statistical significance of the correlations and presented the composed reliability and the average model variance extracted (AVE), which are indices associated with the measured quality. AVE represents the average variance proportion of the items explained in the model. Fig. 2 shows the method adopted in this study.

4. Data analysis and results

4.1. Sample profile

Our sample included 74 men (72.5%) and 28 women (27.5%). The majority of respondents, 39.2%, were between 20 and 25 years old, followed by 27.5% aged from 25 to 30 years old, 16.7% with more than 35 years old, 14.7% between 30 and 35 years old, and only 2% with less than 20 years old.

Regarding the years of experience in the market, most respondents had one to five years of experience, representing 51% of the sample. This was followed by 18.6% with 6–10 years of experience, 12.7% with 10–15 years, 9.8% with more than 15 years, and 7.8% with less than one year.

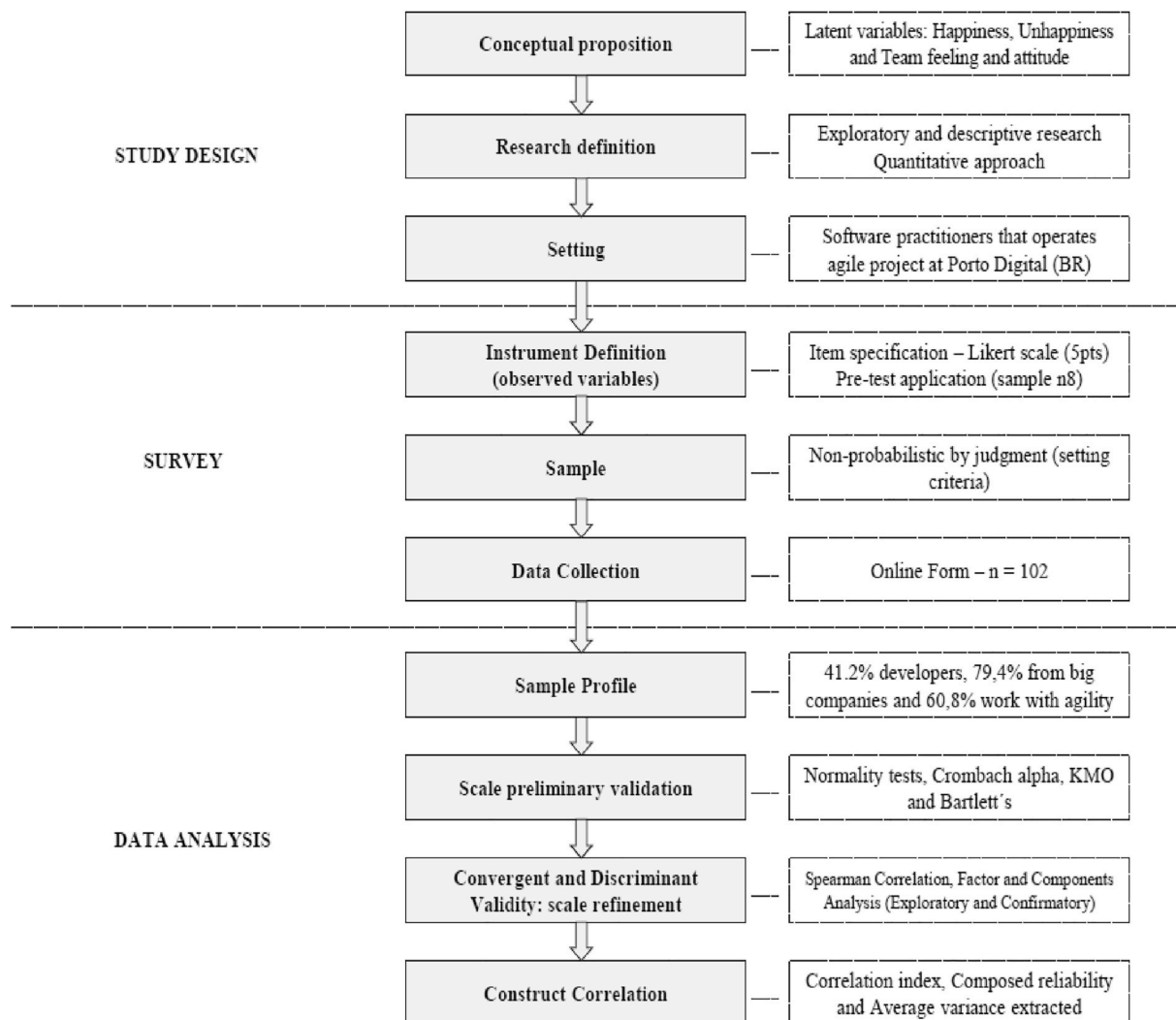


Fig. 2. Research method.

Regarding the job positions, 41.2% were Developers, 23.5% Testers, 6.9% project leaders, 5.9% Scrum Masters/Agile Coaches, 4.9% UX/UI Analysts and 17.6% occupied other positions. Regarding education level, 34.3% of the respondents had a bachelor’s degree, 63.7% were current undergraduates, and 2% had a Ph.D. degree.

Of the 102 respondents, 81 (79.4%) reported that they worked in a large company (more than 100 employees), 17 (16.7%) worked in small companies (10–49 employees), 4 (3.9%) worked in medium-sized companies (50–99 employees), and none worked in micro-companies (less than nine employees). The 102 respondents were from 21 different companies, of which 62 respondents (60.8%) reported the use of agile methodologies in their projects, and 40 participants (39.2%) reported the use of combined traditional and agile practices. Furthermore, 48 participants (47.1%) worked on national projects, 44 (43.1%) on global projects, 8 (7.8%) on local projects, and only 2 (2%) on regional projects.

4.2. Exploratory factor analysis (EFA) and confirmatory factor analysis (CFA)

We performed an analysis of the means and standard deviations of the individual happiness, unhappiness, and team behaviour scales. No respondents were excluded on the basis of being classified as outliers. The Kolmogorov-Smirnov and Shapiro-Wilk tests rejected the hypothesis of data normality.

For 96% of the participants, their emotional state affected their performance. Unhappiness negatively affected productivity (mean: 4.2). The highest rates for emotions associated with unhappiness were observed for anxiety (3.8), insecurity (3.1), boredom (2.9), and frustration (2.9). The lowest rates were observed for unpleasant (2.4), anger (2.6), or unproductive (2.8).

Happiness positively affected productivity (mean = 4.4). The highest rates were observed for engagement (4.6), team spirit (4.5), decision-making (4.4), collaboration (3.8), engagement (3.7), and productivity (3.6). The team behaviours had the most significant results.

Spearman’s correlation coefficients showed significance correlations for all nine happiness items. The most significant correlations were self-confidence and positivity (r = 0.70), communication and collaboration (r = 0.65), and satisfaction and positivity (r = 0.62). We did not remove any variables at this stage, because all items were related to each other.

In the Unhappiness construct, there were ten significant correlations between items, with the highest correlations occurring between feelings of sadness and negativity (0.77), sadness and anxiety (0.56), and negativity and insecurity (0.54). Considering the significance of the correlations, we excluded the variable anger from subsequent analyses.

The team behaviour scale (hereafter referred to as the Team scale) was initially composed of 13 items. Due to the observed significance level, we excluded the following variables: decision making, good communication, creativity, and focus. This left us with a 9-item scale. The most significant correlations in the Team scale were alignment and autonomy (0.63), transparency and defined process (0.50), and learning and alignment (0.49).

Table 2
Alpha Cronbach, Kaiser-Meyer-Olkin, and Bartlett’s tests.

Dimension	Cronbach’s Alpha Reliability Test		Sample Adequacy Measure Kaiser-Meyer-Olkin		Bartlett’s Sphericity Test	
	Value	Evaluation	Value	Evaluation	Value	Evaluation
Happiness	0.884	acceptable	0.865	Adequate	X = 436.122 df 36	satisfactory
Unhappiness	0.856	Acceptable	0.858	Adequate	X = 377.092 df 45	Satisfactory
Team behaviour	0.855	Acceptable	0.845	Adequate	X = 364.199 df 45	Satisfactory

1^a Significant at 1%.

In general, for the three considered scales, the bivariate correlations were significant between indicators associated with the same construct (inter-item within-construct) and the magnitude of the correlations was generally satisfactory, with only a few cases where the correlation was low (0.200 or less). Therefore, we concluded with a base model with 30 observed variables, estimated for 102 observations (without missing data), over three latent variables or constructs.

We performed Cronbach’s alpha for the variables happiness, unhappiness, and the behaviour scales to a reliability test. Then, we measured the sample adequacy using Kaiser-Meyer-Olkin and Barlett’s sphericity tests. Table 2 presents the results of this analysis.

We observed the commonalities and held the model values above 0.5 [61]. In this way, we removed anger from unhappiness and communication from the team variables. To examine the relationship between the observed variables and their constructs (latent variables), we performed an exploratory factor analysis (EFA). We generated two factors for each scale, with an explained variance of 65.2% for happiness, 58.9% for unhappiness, and 59.5% for the team. Table 3 presents a summary of the EFA results.

We then carried out a confirmatory PCA. Nevertheless, in the next step, we tested our research hypotheses and assessed the convergent, discriminant, and AVE validity of the integrated model. Table 4 lists the convergent and discriminant validities.

The diagonal values correspond to convergent validity, and in general, the loads remained above 0.7. The total variance explained was above 50%, which is within the recommended range. The values outside the diagonal correspond to the discriminating factors. There are some values above 0.6 on the same scale, but still show lower values than those along the diagonal values, which demonstrates the discriminative validity of the factors demonstrating the scale quality.

Finally, Table 5 presents the correlation matrix between the latent variables (LV), composite reliability, and construct by component or latent variable. After extracting the principal components, we obtained scalar variables, which allowed the use of parametric correlation methods. The diagonal values had the most significant correlations between the LV (i.e., values outside the diagonal), which indicates discriminant validity. The AVE was above 0.5, and the composite trust was between 0.7 and 0.9, as recommended for all variables.

We calculated the correlation matrix between the latent variables, which were the components generated by confirmatory component analysis (CCA). The diagonal values were more significant than the correlations between latent variables. Thus, there was discriminant validity for all variables. The total explained variance was above 0.5, with reliability between 0.7 and 0.9, as recommended. Table 5 lists the correlation matrix between the latent variables.

In our study, two components measured happiness. The first combined the variables joy, self-confidence, engagement, motivation, productivity, and satisfaction. The total explained variance (AVE) was 58.8%; that is, the Happiness 1 construct explained almost 59% of all variability. It is important to note that values above 50% were considered acceptable. The second component (Happiness 2) combined collaboration, communication, and positivity, with an AVE rate of

Table 3
EFA for happiness, unhappiness, and team behaviour.

Construct	Variable	Component		Construct	Variable	Component		Construct	Variable	Component	
		1	2			1	2			1	2
Happiness	productive	0.733		Unhappiness	anxious		0.553	Team	transparency	0.589	
	engaged	0.795			frustrated	0.656			team learning		0.76
	motivated	0.813			afraid	0.6			autonomy		0.586
	communicative		0.894		bored		0.827		challenging environment		0.7
	collaborative		0.832	delayed	0.712		alignment			0.591	
	joyful	0.646		negative	0.624		team spirit			0.72	
	positive	0.691	0.457	unproductive	0.821		defined process		0.818		
	self-confident	0.732		sad		0.62	agility		0.796		
	satisfied	0.647		unpleasant		0.61	leadership		0.744		

1 Extraction method: Principal component analysis. Rotation method: Varimax with Kaiser normalisation. Converged rotation in three iterations.

Table 4
Convergent and discriminant validity at the item level (confirmatory component analysis).

item / factor	Happiness1	Happiness2	Unhappiness1	Unhappiness2	Team1	Team2
joyful	0.695	0.552	-0.341	-0.386	0.281	0.254
self-confident	0.809	0.670	-0.685	-0.581	0.190	0.204
engaged	0.784	0.528	-0.468	-0.426	0.317	0.256
motivated	0.841	0.556	-0.551	-0.594	0.418	0.368
productive	0.697	0.425	-0.476	-0.361	0.181	0.169
satisfied	0.764	0.595	-0.541	-0.551	0.415	0.365
collaborative	0.540	0.839	-0.421	-0.412	0.185	0.295
communicative	0.403	0.742	-0.223	-0.230	0.192	0.233
positive	0.747	0.872	-0.692	-0.667	0.289	0.367
delayed	-0.385	-0.372	0.673	0.439	-0.058	-0.193
unproductive	-0.473	-0.385	0.749	0.449	-0.079	-0.247
frustrated	-0.486	-0.430	0.715	0.436	-0.385	-0.339
afraid	-0.529	-0.420	0.772	0.567	-0.151	-0.201
negative	-0.626	-0.619	0.843	0.753	-0.295	-0.321
unpleasant	-0.361	-0.512	0.482	0.735	-0.187	-0.283
anxious	-0.471	-0.339	0.513	0.723	-0.066	-0.186
bored	-0.376	-0.349	0.305	0.593	-0.185	-0.097
sad	-0.635	-0.514	0.733	0.857	-0.244	-0.222
agility	0.151	0.167	-0.021	-0.035	0.721	0.410
leadership	0.404	0.223	-0.255	-0.310	0.754	0.415
defined process	0.321	0.278	-0.207	-0.166	0.856	0.563
transparency	0.301	0.188	-0.299	-0.171	0.760	0.526
alignment	0.370	0.402	-0.350	-0.285	0.623	0.853
challenging environment	0.261	0.273	-0.190	-0.233	0.244	0.636
team learning	0.322	0.263	-0.348	-0.260	0.390	0.747
autonomy	0.160	0.265	-0.220	-0.125	0.581	0.784
team spirit	0.139	0.102	-0.096	-0.039	0.366	0.639

¹All factor loads are significant at 1%.

Table 5
Latent correlation matrix.

	Happiness1	Happiness 2	Unhappiness1	Unhappiness 2	Team1	Team2	Criteria
Happiness1	0.767						
Happiness1	0.730	0.819					
Unhappiness1	-0.677	-0.608	0.752				
Unhappiness1	-0.644	-0.592	0.724	0.733			
Team1	0.398	0.282	-0.276	-0.238	0.774		
Team2	0.358	0.379	-0.352	-0.275	0.625	0.737	
Composite Reliability	0.895	0.859	0.866	0.820	0.856	0.854	0,7
Average Variance Extracted (AVE)	0.588	0.671	0.566	0.537	0.600	0.543	0,5

1 Diagonal values are the square root of the stroke. is the results demonstrate discriminant validity, as the diagonal values are more significant than the correlations between the VL (values outside the diagonal).

2 All correlations are significant at 1%.

67.1%. Happiness 1 and Happiness 2 showed a strong positive correlation, $r = 0.730$.

Two components were also associated with unhappiness. The first component combined delay, low productivity, frustration, insecurity, and negativity, with an AVE rate of almost 57%. The second group gathered antipathy, anxiety, boredom, and sadness, with an AVE rate of 53.7%.

The team constructs, similar to the previous two, were composed of two components. The first construct combined agility, leadership, a defined process, and transparency, with an AVE of 60%. Finally, the second component combined alignment, a challenging environment, learning, autonomy, and team spirit, with an AVE rate of 54.3%.

Based on the above analyses, it was possible to considerably reduce the number of variables. Initially, the questionnaire contained 37 questions. After applying the CFA, we arrived at six variables and three constructs. These new variables showed significant correlations. The Happiness 1 component showed a weak positive correlation with Team 1 ($\rho = 0.398$, $p < 0.05$) and Team 2 ($\rho = 0.358$, $p < 0.05$). Thus, despite a weak association, we observed that the Happiness 1 data was positively associated with Team 1 and Team 2. However, it was not possible to determine a causal relationship because improvements in the happiness construct can positively impact the ability team and vice versa. That is, better performance in Team 1 and Team 2 may be accompanied by greater happiness. Happiness 2 also showed a positive correlation with Team 1 ($\rho = 0.282$, $p < 0.05$) and Team 2 ($\rho = 0.379$, $p < 0.05$).

All components of unhappiness showed a negative correlation with the two Team components. Thus, the unhappiness construct or its variables can lower the team's performance. However, it was not possible to establish a causal relationship between variables. That is, the worse the team's result, the more unhappy the employee will be. The Unhappiness 1 component was negatively correlated with Team 1 ($\rho = 0.276$, $p < 0.05$) and Team 2 ($\rho = 0.352$, $p < 0.05$). The Unhappiness 2 component also showed a negative association with Team 1 ($\rho = 0.238$, $p < 0.05$) and Team 2 ($\rho = 0.275$, $p < 0.05$).

Factor analysis combined groups of variables into two similar categories. Thus, it was demonstrated that other feelings and behaviours can follow the occurrence of certain feelings. In addition, we found that positive feelings had positive associations with the team's performance, and negative emotions were associated with declines in the team's production levels.

5. Discussion

The benefits of promoting happiness among developers have been demonstrated empirically in previous research, and this is especially true for software development productivity and software quality. Graziotin's [15] results show that solving problems of unhappiness can limit damage to several factors at the individual, artifact, and process levels.

Around the world, the software development community faces many uncertainties due to changes in the work environment caused by the COVID-19 pandemic. Working at the home office is associated with several unpleasant environmental factors, such as having to meet colleagues virtually and working in more dynamic and varied hours. Despite this context, Ralph et al. identified that software developers continue to work productively [8]. Langfred [62] observed that individual autonomy increases when qualified people act independently toward the teams' shared goals. Thus, an alignment is necessary between the organisation and the team's goals to increase the team's shared understanding and autonomy.

One of the aspects observed during the first wave of the COVID-19 pandemic was the inclusion and engagement of team members in the activities and goals definition of the team. Our findings demonstrate that these factors reflect on well-being which can be proven by our engagement rate (4.6). This supports the results of Graziotin's study [15], wherein the authors state that high work engagement and perseverance

occur when developers are happy [15]. Additionally, our findings are consistent with Singh et al. [47], who found that happiness has a significant positive relationship with work engagement, and with Stairs and Galpin [63], who found that happiness is beneficial in increasing levels of engagement.

According to Dutschke et al. [64], happiness attribution is placed on group/organisational components rather than individual motivations. Their results highlight that the details of the group and its organisational dynamics are associated with individual well-being. Our study corroborates these findings and shows that when team members are available and open to help with any problem or question, that this promotes greater security and team spirit, which in turn positively impacts team member activities. Our results also identify team spirit as a key factor during the COVID-19 pandemic in generating well-being and happiness.

Nevertheless, satisfaction comes with decision-making and the level of challenge within the work environment [30]. Given the importance people attach to happiness, it is reasonable to expect that decisions that people make are driven mainly by the anticipated happiness that decision would bring, which we refer to as the anticipated happiness utility of the choice [65]. Surprisingly, in the middle of an unprecedented pandemic, challenges and opportunities to engage in decision-making seem to bring happiness to software engineers, as corroborated by our population index.

Thus, the pandemic and the need to work from home provided a unique opportunity to understand more about developer productivity and find ways of providing guidance for developers who work remotely or collaborate with remote members of their [13] team. Software developers may require highly intense periods of focused work, but they also rely on close collaboration to develop creative software. In particular, coping with a pandemic is an inherently collaborative process. In our study, the collaboration rate remained above average. We can therefore conclude that happy developers are also more collaborative team members, which leads to greater overall collaboration.

Happy employees tend to interact more with other employees in the organisation and form strong social bonds that make their work more meaningful and satisfying [47]. Previous research [15] has reported that high work engagement and perseverance occurs when respondents are happy. Moreover, happiness is directly [15] and indirectly [47] related to work engagement. However, it is not the case that those who are more engaged with their jobs and their colleagues work harder or smarter [66]. Yet, people who are in good moods tend to engage in behaviours that support their mood. This is important because the most significant competitive advantage in the modern economy is a positive and engaged workforce [66]. Previous research has demonstrated that the overall level of engagement in the workforce has increased in recent years ([6]). In our study, engagement was strongly related to happiness.

Alignment often requires some level of control, which tends to reduce absolute autonomy. The relationship between autonomy and self-management is not new [67]. Moe et al. [68] observed that certain forms of detailed control by management inhibits autonomy, because the entire point of autonomy is that the teams should control themselves. Research has shown [67] that team members in large-scale agile projects are often excluded from goal-setting processes. The authors state that because decision-making is limited, the team cannot fully control how all tasks are conducted, and they must adjust their processes to conform with other teams and actors. Within the context of the pandemic, our study showed a positive correlation between team alignment with stakeholders and autonomy.

Bureaucratic companies rely on a hierarchy, which is in contrast with self-organizing teams [67]. This type of organisation tends to present a more rigid planning structure, rather than relying on iterative learning [69]. In other words, the need to constantly align with leadership has a negative impact on team learning.

In contrast, enabling leadership fosters some team processes, such as team learning [70]. According to Salas-Vallina and Alegre [71], the organisational learning literature has neglected to investigate the role of

the organisational conditions that facilitate learning and happiness at work. The authors relate altruistic leadership with organisational learning by demonstrating the fundamental role of organisational learning in improving happiness at work. Positive attitudes, particularly happiness at work, are an outcome of organisational learning. However, organisational and team learning is related to happiness, and more centralised leadership demands constant alignment, and thus generates fewer learning opportunities. In our sample, the correlation between team learning and alignment was weak.

Sentiment analysis of the text written by developers in their issues and tickets has shown that the negative clues in a text can be related to developer emotions, such as sadness, disgust, fear, or anger [72]. Our study is similar in that we found a strong correlation between negative feelings and sadness. Moreover, we found that these negative feelings can damage one's productivity.

COVID-19 has dramatically shifted affordances, requiring a new communication pattern with respect to the frequency, length, and style of workplace communication [11]. To maintain collaboration and communication among teams, the tools used play an essential role in the behaviour of the team members, allowing the facilitation, automation, and control of the entire development process. Possessing adequate tools has been essential during the pandemic, because the distance associated with remote work directly or indirectly aggravates coordination and control problems through its adverse effects on communication.

Thus, we can see that organisations can positively impact their developers' ability to handle COVID-19 in several ways. For example, simulating a work environment at home and facilitating more interactions among developers, as depicted in the Neto et al. [6] study, and reversing the negative impact that working at home can have on the balance between one's work and personal life [47]. Organisations need to establish a balance to continue to operate during the pandemic, and this balance can help them maintain an experienced and trained team and be ready to grow if and when the pandemic ends.

Therefore, during the coronavirus outbreak, several software companies have encouraged social coexistence practices, as reported by NicCanna et al. [14]. This includes offering social connections, such as pizza on Fridays, music knowledge questionnaires, and shared meals in which groups of people from different countries and offices meet through videoconferencing for a casual chat. Alternatively, other social practices, such as playing game rounds during work hours, have emerged as methods to keep developers happy at work [42].

These social circumstances promote an environment of collaboration and communication, in addition to positivity. This "positivity" can help developers improve their resilience to deal with difficulties, and to recover from traumatic or unpleasant events. Software companies should realise that by adopting positive psychological methods, they can cultivate team satisfaction and well-being.

In our study, collaboration, communication, and positivity were combined into a construct which we labelled Happiness 2. This demonstrates that, for our sample, the shared variance between them was relatively high. This corroborates research by Fagerholm et al. [35], which indicated an intrinsic relation between the accessible communication established within the team and team members' happiness or unhappiness. Our results confirmed the influence of good communication on happiness and, consequently, team productivity. In addition, we found that an increase in positivity was associated with an increase in communication and collaboration.

Joy, self-confidence, motivation, productivity, and satisfaction were grouped into a construct which we labelled Happiness 1. This grouping of constructs had a high common variance, demonstrating that the improvement of some indicators can have a positive impact on the others.

The criteria aggregation in a single construct, proposed by factor analysis, presented results consistent with the literature. Motivated people are engaged and focused [32,33], and happy software engineers are the ones who are satisfied [15,32]. Moreover, job satisfaction affects

physical and mental health [32] and factors such as these for greater productivity and better performance [22]. In addition, there is a clear relationship between a developer's self-confidence and happiness within the software development process [15].

A negative state of mind or mood has also gained attention in the literature for its impact on a developer's productivity and ability to react to undesirable parts of their job [73]. By connecting these negative feelings, we can form a relationship between them. These two constructs formed as Unhappiness 1 and 2. These groups referred to the negative results or experiences that impact external pressures (Unhappiness 1), and internal pressures and negative feelings (Unhappiness 2).

Stress, isolation, travel restrictions, business foreclosures, and educational institutions, daycares, and gyms closing have all affected those who must now work at home. The pandemic's severity and uncertainty about the future cause frustration, anxiety, and fear [51,74]. Therefore, it is likely that many developers will experience negative feelings as a result of the pandemic. Emerging research on COVID-19 has also shown a negative effect on well-being, particularly on anxiety [75]. The results of the present study demonstrate that developers are suffering during this period with feelings of sadness, anxiety, and frustration, which are all associated with unhappiness.

Lack of productivity or "inflow moments" can cause developers to become frustrated and stuck in their work [73]. The failure to overcome these obstacles can elicit a sense of frustration and insecurity in developers, which can then negatively impact their productivity. Unhappiness has been linked to consequences such as low code quality, low productivity, stress, burnout, and frustration [54].

The other groups of negative feelings and emotions that we investigated were antipathy (unpleasant), anxiety, boredom (bored), and sadness (Unhappiness 2). An organisation can benefit from limiting these negative experiences. Therefore, we need to understand these factors and their effects. Moreover, although research has shown that negative emotions are often correlated with low progress, in certain situations the same negative emotions might be necessary to solve a problem and lead to subsequent higher progress. That is, occasionally being frustrated by a task might provide indirect benefits [73]. Therefore, understanding the nuances of these emotions might help developers to harness these negative feelings towards overcoming a problem.

We also observed some factors or behaviours related to the participants' team or projects, such as agility, leadership, defined processes, and transparency. Previous research has identified that these are external causes related or attributable to people with whom developers interact [54]. These factors, in isolation, were all strongly correlated with happiness, and could be combined and presented as Team 1. Team 2 was composed of alignment, challenging work environment, learning, autonomy, and team spirit.

During the COVID-19 pandemic, the demand for a defined process has been more essential than usual. Well-defined processes improve software development cycle's development, planning, and implementation. Furthermore, the pandemic has also, in some cases, provided transparency, which provided members of our sample with a better experience and happiness. Thus, COVID-19 does not necessarily result in reduced productivity [6] or unhappiness. Agile processes, self-organized and autonomous teams, and project leaders always willing to assist and motivate can make a considerable difference during the COVID-19 pandemic.

By understanding these behaviours, team members and organisational leaders might help foster these factors to improve their developers' happiness and team productivity during and after the pandemic. Work on these team behaviours can help practitioners improve group happiness. Furthermore, understanding which team aspects might cause unhappiness can allow teams and organisations to use more empathy and act in the team's best interests. Moreover, team leaders and organisations can analyse the results of this study and try to raise developer happiness and mitigate unhappiness factors. Thus,

creating policies and processes that foster these team behaviours should be planned and supported by organisations, because they can induce a sustained improvement in well-being after the pandemic.

In our study, we analysed three hypotheses regarding the existence of statistically significant associations between the constructs. Our findings showed supported all three hypotheses, which corroborates the current literature. Unhappiness was associated with worsening team behaviour and a reduction in happiness. Furthermore, in the observed measures, team behaviour and happiness varied in the same direction: an increase in happiness was associated with an increase in positive team behavioural characteristics.

Due to the outbreak of COVID-19, software developers were forced to work from home. The demanded social distance requirements created a challenging environment that was very different from any other remote work scenario before COVID-19. Team spirit has allowed teams to continue their projects, once they understand their strategies, and to promote social relationships. Furthermore, organisations can positively impact the ability of their developers to cope with the COVID-19 pandemic by encouraging learning and fostering an autonomous environment.

Finally, it is essential to point out that our findings must be read in the work and life contexts of the extreme conditions faced by the participants. Based on our analysis, we found that the situation during the pandemic did not necessarily result in reduced productivity or unhappiness for developers. However, even during the pandemic, team behaviour is associated with feelings of happiness. Thus, productivity, engagement, transparency, and agility are positively related to software developer happiness.

6. Threats to validity

During the study, some threats to validity were addressed. The authors avoided the main threats by following the guidelines presented by Kitchenham on how to survey software engineers [76]. However, some threats to the validity of the present study still exist.

6.1. Conclusion validity

Conclusion validity refers to how the data collection techniques and treatment reflect the reality of the phenomenon under investigation. Only the results that were shown to be statistically significant (at least 1%) were maintained for analysis and discussion. Namely, the sample adequacy tests (Bartlett's and KMO), correlations between items and constructs, principal components, and validity demonstrate the accuracy of the results. It is noteworthy that it is not possible to establish causal relationships between the constructs of happiness and the team's behaviour and attitudes. As previously mentioned, our findings reflect a period of extreme conditions; therefore, our data and conclusions are constrained to pandemic or crisis periods. However, software companies and practitioners could consider the research presented here to improve their remote work environments in any situation.

6.2. Internal validity

Internal validity refers to how we can be that a particular treatment led to the observed result. We performed Cronbach's alpha tests and composite reliability to assess the scales, which proved to be satisfactory. In addition, we estimated the convergent and discriminant validity of the construct. This allows us to state that these were adequately identified based on the current literature and the selected sample characteristics.

6.3. External validity

External validity refers to the capacity to generalize the results of a study. An external threat of the present study could be that the sample

was composed of 102 respondents from a population of more than 9 thousand employees. We therefore cannot necessarily generalize the results because the sample was not random. However, we calculated the sample size based on Cochran [60] and in a population of 9000 employees [58]. The population standard deviation was estimated using a sample standard deviation of 1.1. The absolute tolerable error was 20% of the standard deviation (0.22), with a 95% confidence interval. The minimum sample size was 96 participants. In addition, we performed sample adequacy tests which proved to be adequate for adopting appropriate statistical techniques. We consider the sample to be representative because it is composed of employees from the most relevant tech companies in the cluster. Therefore, our results may not be generalizable to all Brazilian regions and software teams in several contexts (e.g., larger teams and different project domains). However, we believe that the obstacles and solutions presented here can motivate software companies to understand the developer's happiness during the pandemic.

6.4. Construct validity

Construct validity refers to how an instrument can produce similar results with different data collection approaches. Such validity was assessed by conducting our survey based on a previous survey. In addition, we conducted a pilot study with 67 participants who worked in software companies. This pilot helped us to refine the questionnaire, enhancing its construct validity.

7. Conclusion

The pandemic has accelerated the redesign of several activities in many sectors, restructuring how teams manage their work. Software developers in particular have undergone an intense change, drastically altering their work environments and team interactions. Dealing with the uncertainties of the pandemic, the fears of an eventual infection, mourning the loss of friends and relatives, and reducing social interaction has become a mandatory burden. In addition, the pandemic and associated emotions have affected practitioners' work development and results.

The present study sought to assess the relationships between several software development positive and negative feelings, with their team's behaviour and results, during a crisis period such as the COVID-19 pandemic. Our study provides several novel findings. First, feelings associated with happiness positively influence a team's behaviour. Second, the feeling of unhappiness negatively affects work results and productivity. Thus, if the professional's feelings are affected positively or negatively by the environment, this will impact their performance. This evidence demonstrates that mixed feelings, such as those associated with the COVID-19 pandemic, are especially critical for software developers.

Third, our research indicates that there is a negative association between happiness and unhappiness. Hence, promoting positive feelings may be associated with a reduction in unhappiness's negative feelings. However, it is not a causal relationship; such information traces a vital path that managers and companies can explore to combat unhappiness with happiness. In light of our first finding, increasing the happiness of team members may influence the team's commitment.

The scales used and refined should be considered viable for use in future research. In factor analysis and principal components, it was proposed to aggregate certain sets of feelings. This demonstrates that these groups of feelings in the studied sample have a common variance. That is, they covary. In practical terms, exploring one or more core feelings in the groups (Happiness 1, Happiness 2, Unhappiness 1, Unhappiness 2, Team 1, and Team 2) can affect other feelings in the same class. The fourth key contribution of the present study is that the scale proved to be viable for use in other contexts. It provides a mechanism for future researchers to test these constructs in other settings and other

target groups, and to compare their findings to those presented in this study.

Our findings outline an essential roadmap for practitioners, managers, and companies in the technology area to explore their feelings, culminating in better employee well-being and improved group performance.

Author statement

Marcelo Marinho: Conceptualization, Methodology, Data curation, Writing – original draft preparation, Writing- Reviewing and Editing; Luís Amorim: Data curation, Writing – original draft preparation; Rafael Camara: Data curation, Writing – original draft preparation; Brigitte Renata Oliveira: Methodology, Formal analysis; Marcos Sobral: Methodology, Formal analysis; Suzana Sampaio: Conceptualization, Methodology, Data curation, Writing – original draft preparation, Writing- Reviewing and Editing.

A Appendix. Questionnaire

Applied Questionnaire Statements

1. My performance is negatively impacted whenever I am sad.
2. My performance is positively impacted whenever I am happy.

Individual Happiness/Unhappiness feelings

1. How frequently did you feel *anger* during any task execution or situation during this COVID pandemic time?
2. How frequently did you feel you were *productive* during this COVID pandemic time?
3. How frequently did you feel you were *anxious* during this COVID pandemic time?
4. How frequently did you feel you were *engaged* with task execution during this COVID pandemic time?
5. How frequently did you feel you were *frustrated* during this COVID pandemic time?
6. How frequently did you feel you were *motivated* during this COVID pandemic time?
7. How frequently did you feel you were *afraid* during this COVID pandemic time?
8. How frequently did you feel you were *satisfied* during this COVID pandemic time?
9. How frequently did you feel you were *bored* during this COVID pandemic time?
10. How frequently did you feel you were *communicative* during this COVID pandemic time?
11. How frequently did you feel you were *collaborative* during this COVID pandemic time?
12. How frequently did you feel you had tasks in *delay* during this COVID pandemic time?
13. How frequently did you feel moments of *joyful* during this COVID pandemic time?
14. How frequently did you feel *negative* during this COVID pandemic time?
15. How frequently did you feel *positive* during this COVID pandemic time?
16. How frequently did you feel *good or self-confident* during this COVID pandemic time?
17. How frequently did you feel *unproductive* during this COVID pandemic time?
18. How frequently did you feel *happy* during this COVID pandemic time?
19. How frequently did you feel *sad* during this COVID pandemic time?

20. How frequently did you feel *unpleasant* during this COVID pandemic time?

Team behaviors perspective statements

1. (*Transparency*) During this COVID pandemic time, development cycles' tasks and goals were always disposed of in an accessible mode to everyone from my team, which eased communication and made me more engaged and satisfied.
2. (*Team learning*) I understand my tasks' importance, and I am free to choose and learn during their execution. It cheers me up and positively affects my performance.
3. (*Autonomy*) During this COVID pandemic time, my team makes decisions and discusses the whole software development process cohesively and objectively. It makes me feel included and positively affects my performance.
4. (*Creativity*) Generating new ideas is something recurrent and easy for me within the project. That way I become more and more creative, impact more on results and feel meaningful and happy.
5. (*Challenging Environment*) During this COVID pandemic time, my work environment shows up as challenging and full of decisions to be made daily. It positively affects my performance.
6. (*Alignment*) Customers' expectations and my team's reality are constantly aligned, including everyone from the team, making the software development process's experience engaging and pleasant.
7. (*Team spirit*) My teammates are always available and willing to help with any issue or doubt I might have. It promotes more security and team spirit, which positively affects my task's performance.
8. (*Defined process*) There are well-defined processes for the whole software development cycle in my project, and it makes our development execution better planned and carried out, consequently promoting a better experience to me.
9. (*Agility*) My project follows agile practices for software development, and I'm aware of each step, contributing with the team to achieve all of their goals.
10. (*Leadership*) The project's leaderships are always open to help and motivate me during the whole software development process, recognising my wins and successes, making me happy and eager to improve each day.
11. (*Good communication*) During the pandemic, communication between my team members happens quickly and effectively, both formally and informally. This communication positively affects my performance.
12. (*Focus*) I tend to keep my attention on my activities even if they become complex and laborious. If it takes time to resolve, I start to get stressed and feel incapable.
13. (*Decision making*) When I feel good, I make better choices for project maintenance and look for new activities or help other colleagues as soon as I finish my demands. However, I feel helpful and vital to the team, which makes me feel good.

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