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Performance of SCRUM teams in the transition to hybrid work

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Abstract: The COVID-19 pandemic required a product engineering department in an aeronautical company to transition from on-site work to remote work and later to a hybrid model, influencing teams that applied SCRUM. This study assessed whether this shift affected performance related to engagement, trust, and mutual support. A survey was carried out assessing seven factors that influence performance: autonomy, communication, roles, ceremonies, engagement, trust, and mutual support. Data were collected from 132 respondents via a 5-point Likert scale questionnaire, comparing on-site (pre-pandemic) versus hybrid (post-pandemic) work environments. The PLS-SEM results indicated stability in engagement, trust, and mutual support suggesting that the hybrid model did not alter these essential performance elements. However, difficulties associated with roles and ceremonies revealed knowledge gaps in SCRUM, particularly among SCRUM Masters. The study expands the understanding of SCRUM practices in product engineering contexts outside software development and provides insights for improving its adoption in hybrid environments.

Keywords: Agile Project Management, SCRUM, Project Teams, Performance, Hybrid work, WFH, Work from home

1 Introduction

The COVID-19 pandemic required Brazilian organizations to rapidly shift from face-to-face routines to remote work beginning in March 2020. Telework, defined as activities performed outside the employer's premises supported by communication technologies (BRASIL, 2011; Hermogenes *et al*., 2020), created significant challenges for product engineering teams that depended on in-person collaboration. Multidisciplinary and co-located groups had to replace established practices with communication restricted to virtual meetings and electronic messages. Agile teams experienced additional difficulties, since SCRUM was conceived for environments with intensive interaction and collaborative cycles (Sutherland, 2014; Schwaber and Sutherland, 2017).

Studies conducted during the pandemic reported obstacles related to Agile ceremonies, team autonomy and leadership behaviour, highlighting persistent issues in remote and hybrid contexts (Mancl and Fraser, 2020; de Morais Barroca Filho *et al*., 2021; Marek, Wińska and Dąbrowski, 2021). Although some analyses indicated stable or improved agile team performance, communication problems, longer meetings and adaptations of agile practices remained common (Badiale, 2020; Brodnicki, 2021; Marek, Wińska and Dąbrowski, 2021; Salnikov, 2021; Schmidtner, Doering and Timinger, 2021). Several studies reported reduced collaboration, fewer spontaneous exchanges and weakened communication quality, especially among teams previously accustomed to in-person work (Badiale, 2020; Jose, 2021; Karlsson and Skötte, 2021; Neumann, Bogdanov and Sager, 2022).

Performance assessment in product development is complex due to intangible outputs (Ramírez and Nembhard, 2004; Bosch-Sijtsema, Ruohomäki and Vartiainen, 2009). Several factors have been found to influence agile team performance in the extant literature. A systematic literature review carried out by the authors showed 8 different factors ranging from inputs (Individual and Group characteristics, Stage of team development, Nature of task, Organizational context and Supervisory behaviors), processes (Internal and External processes) e output (Agile team productivity outcomes and Attitudinal and Behavioral outcomes).

More recent works on agile team performance operating in virtual or hybrid environments reported variance in results. Some showed evidence of performance stability, others improvement or decline. Positive effects were linked to reduced commuting and improved concentration, whereas negative outcomes related to weakened trust, fewer SCRUM ceremonies and increased managerial control (Jose, 2021; Ozkan, Erdil and Gök, 2022). Although remote SCRUM appears feasible, many adaptations shift teams away from agile principles. Existing research remains concentrated on software contexts, with limited investigation of other sectors and no structured comparisons of team performance across face-to-face, remote and hybrid settings. This study addresses this gap by examining SCRUM use in product engineering and its performance implications under hybrid work.

Based on this context, this study aimed at answering the following question: *Was there a change in the relationships between the factors that influence the performance of agile teams in the migration from face-to-face to hybrid work?* The research applied a quantitative survey focused on seven factors from the IPO (De Melo et al, 2013) model: autonomy, communication, roles, ceremonies, engagement, trust and mutual support. Items adapted from Lindsjørn *et al*. (2016), Buvik and Tkalich (2022) and Kadenic, Koumaditis and Junker-Jensen (2023) were answered for the pre-pandemic face-to-face period and for the hybrid contexts. Responses on a five-point Likert scale were analyzed using PLS SEM.

The study offers practical relevance by identifying how SCRUM practices in product engineering were maintained, altered or reduced in the hybrid regime, supporting managerial decisions on training, ceremonies and integration of distributed teams. The theoretical contribution lies in examining a still underexplored context and providing empirical evidence on performance factors in post-pandemic hybrid work models.

2 Theorical review

Agile Project Management and SCRUM

Agile Project Management (APM) emerged as an alternative to traditional management approaches, particularly in software development, which requires constant adaptation (Highsmith, 2002; Leffingwell, 2010; Ribeiro *et al*., 2017). Its consolidation through the Agile Manifesto emphasized values centered on interaction, customer collaboration and responsiveness to change (Beck *et al*., 2001). These principles rely on continuous communication, direct exchanges and shared problem-solving, qualities naturally supported by face-to-face contexts. Several principles highlight this dependence, such as the emphasis on in-person communication, daily collaboration between business and technical professionals and the need for motivated individuals supported by an appropriate environment.

Within this perspective, SCRUM gained prominence after its introduction by Schwaber and Sutherland in 1995 and later formalization in the SCRUM Guide (Schwaber and Sutherland, 2017; SCRUM, 2017). The method operates through short cycles in which work is planned, inspected and improved. SCRUM defines the roles of Product Owner, SCRUM Master and development team and organizes work through ceremonies such as Sprint Planning, Daily Meeting, Sprint Review and Sprint Retrospective, supported by artifacts including the Product Backlog, Sprint Backlog and increment. Its design originally assumed co-located teams, since proximity promotes rapid information flow, trust and effective self-management. Authors such as Sutherland (2014) argue that fundamental agile decisions depend on rich interaction and spontaneous exchange.

Research has shown that remote environments affect these foundations. Reported difficulties include extended ceremonies, increased managerial control, lower engagement in daily meetings and the partial discontinuation of key practices (Mancl and Fraser, 2020; de Morais Barroca Filho *et al*., 2021; Marek, Wińska and Dąbrowski, 2021). Self-management is also challenged when communication becomes fully mediated, leading to reduced collaboration and weakened alignment, as noted by Moe, Dingsøyr and Dybå (2010). In these conditions, the SCRUM Master may shift from a facilitator role to one of monitoring, diverging from agile principles. Autonomous teams, according to Guzzo and Dickson (1996), rely on shared responsibility and mutual trust, elements more difficult to sustain without direct interaction.

Although SCRUM provides a strong foundation for complex and changing environments, its effectiveness presumes conditions typical of in-person work, such as immediate communication, clear visibility of tasks and strengthened interpersonal relationships. Applying SCRUM in remote or hybrid models therefore requires adaptations capable of preserving these elements and avoiding structural limitations that may hinder team performance.

Remote and Hybrid Work

Remote work was already discussed in the literature before 2020, but its relevance expanded significantly after the pandemic. Several terms describe work performed away

from company facilities with technological support, including telework, teleactivity, virtual work and work from home (Nogueira and Patini, 2012; Haubrich and Froehlich, 2020). Campos (2020) defines remote work as any activity executed at a distance, and some authors include distributed teams across different locations. The pandemic also reinforced the use of the term hybrid work, characterized by alternating remote and on-site routines (Barrero, Bloom and Davis, 2021; Uru, Gozukara and Tezcan, 2022).

In Brazil, remote work regulations evolved from Law No. 12.551/2011 (BRASIL, 2011) to updates in 2017 concerning equipment and ergonomics and, later, the official recognition of hybrid work in 2022. Studies highlight benefits such as cost reduction, expansion of hiring possibilities and reduced commuting, but also point to drawbacks that include isolation, communication difficulties, work overload and challenges in maintaining boundaries between personal and professional life (Rafalski and De Andrade, 2015; Haubrich and Froehlich, 2020). Companies also report concerns involving organizational culture, information security and increased technological demands (Jordão, 2020).

The hybrid model has gained attention as a means to combine flexibility with the advantages of face-to-face interaction. Research shows that periodic in-person contact supports training, strengthens social ties and facilitates complex collaborative activities (Mello, 1999; Barrero, Bloom and Davis, 2021). The pandemic accelerated this transition, with 43 percent of Brazilian companies adopting remote work in 2020 (Brasil, 2020). Studies report positive evaluations by both workers and organizations due to reduced commuting and increased flexibility (Granato, 2021).

Evidence indicates that many organizations adopted remote work abruptly and later implemented more structured hybrid arrangements. Case studies show efforts to provide equipment, ensure ergonomic standards and progressively restore on-site interaction to improve collaboration and team cohesion. Overall, research suggests that remote and hybrid models offer substantial advantages but also require continuous adjustments to maintain productivity, integration and organizational culture.

Agile Methods in a Remote context

Research on remote work during the pandemic stimulated investigations into how agile methods, particularly SCRUM, respond to the absence of face-to-face interaction, historically considered central to these approaches (Highsmith, 2009; Schwaber and Sutherland, 2017). Our review identified 25 studies published between 2020 and 2023, almost all situated in the software industry, which reveals the scarcity of analyses in other sectors. Overall, findings show that SCRUM teams working remotely encounter difficulties related to communication, ceremonies, agile culture and control practices. Several studies reported reduced collaboration, fewer spontaneous exchanges and weakened communication quality, especially among teams previously accustomed to in-person work (Badiale, 2020; Jose, 2021; Karlsson and Skötte, 2021; Neumann, Bogdanov and Sager, 2022). Even when distributed teams sustained effective digital communication, most cases indicated losses in interaction.

SCRUM ceremonies also experienced recurrent disruptions. Sixteen studies reported reduced discipline in planning, daily meetings and reviews, longer and more exhausting sessions and signs of misalignment or weakened agile culture (Brodnicki, 2021; Christoffersson and Djup, 2021; de Morais Barroca Filho *et al*., 2021). In response, teams

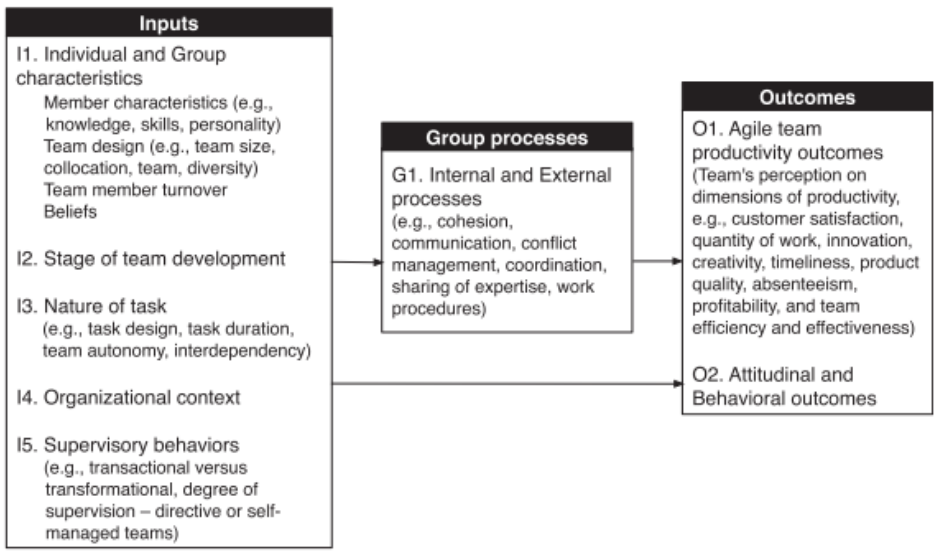
adopted digital tools, reorganized boards, modified sprint cycles or even migrated to Kanban when SCRUM proved difficult to maintain remotely (Cruz, Fernandes Junior and Sardinha, 2021; De Souza Santos and Ralph, 2022). Some initiatives introduced complementary practices to reinforce communication and cohesion, such as adapted frameworks and structured workshops (Nankap *et al*., 2022; Topp *et al*., 2022).

Performance results varied. Six studies reported stability, six observed improvements and three identified declines. Gains were associated with fewer commutes and better concentration (Jose, 2021), whereas decreases were linked to diminished trust, reduced ceremonies and stronger managerial control (Ozkan, Erdil and Gök, 2022). The review concludes that, although remote SCRUM is viable, many adaptations distance teams from agile principles and revive elements of traditional management. A major scientific gap remains nearly all research focuses on software environments, with only one study addressing a different sector. No investigations were found that compare face-to-face, remote and hybrid contexts using structured performance metrics. This study therefore addresses an underexplored area by examining agile practices in product engineering and evaluating how the transition to hybrid work affects performance factors and SCRUM application in an industrial setting.

Performance in Agile Teams – I-P-O Model

The Input Process Output (I P O) model is widely applied to evaluate team performance and was adapted to agile development by De Melo *et al*. (2013), as shown in Figure 1.

Figure 1 – Conceptual performance model for working in agile teams



Source: De Melo *et al*. (2013, fig. 1)

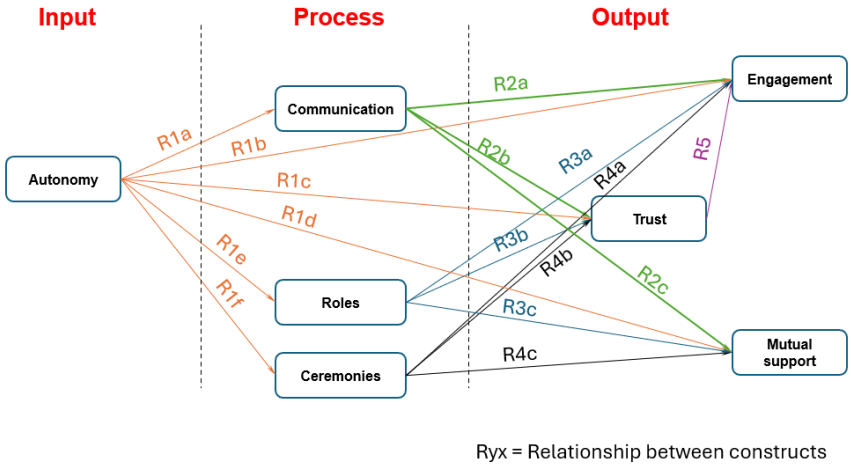
The model explains how team characteristics, their interactions and the results they generate relate to each other in agile environments. Inputs refer to individual and collective attributes that shape team functioning, with autonomy highlighted as a central element because it establishes how teams plan and execute work (Guzzo and Dickson, 1996; Buvik and Tkalich, 2022). Studies indicate that autonomy, maturity and team composition influence responsiveness, cohesion and learning (Lee and Xia, 2010; Kadenic, Koumaditis and Junker-Jensen, 2023). Processes comprise the interactions and routines that link inputs to outcomes. In SCRUM teams, communication, roles and ceremonies form the core of this dimension. Communication supports coordination and knowledge sharing (Lindsjørn *et al*., 2016). The roles of Product Owner, SCRUM Master and development team organize responsibilities and promote self-organization (Schwaber and Sutherland, 2017). The SCRUM ceremonies establish structured cycles of inspection and adaptation that connect team inputs, processes and outcomes. These recurring practices support coordination, shared understanding and learning, contributing to effectiveness, efficiency, satisfaction and overall project success in agile teams (Chow and Cao, 2008; Lindsjørn *et al*., 2016; Kadenic, Koumaditis and Junker-Jensen, 2023).

Outputs represent team results and, in this study, correspond to engagement, trust and mutual support. Engagement expresses a positive and dedicated mindset (Buvik and Tkalich, 2022). Trust refers to expectations regarding integrity and competence (Mayer *et al*., 1995). Mutual support captures members' willingness to help one another (Lindsjørn *et al*., 2016). The I P O model therefore integrates autonomy, SCRUM practices and behavioral indicators to explain performance in agile teams.

3 Method

The study adopted a quantitative design using an explanatory survey, an approach suited for testing predefined theoretical relationships between constructs and hypotheses, as noted by Forza (2002). The construction of the theoretical model was guided by the identification of SCRUM factors most affected by the transition to remote work. These elements were reorganized according to the Input Process Output (I P O) structure proposed by De Melo *et al*. (2013), which enabled the definition of central constructs and their theoretical relationships. From this reorganization, seven factors were established for analysis: autonomy, communication, roles, ceremonies, engagement, trust and mutual support. These constructs were consolidated from the contributions of Lindsjørn *et al*. (2016), Buvik and Tkalich (2022) and Kadenic, Koumaditis and Junker-Jensen (2023), and are presented in Figure 2.

Figure 2 – Theoretical model of performance of agile teams using the SCRUM methods



Source: The authors

Autonomy was positioned as the primary input, since it represents the team's capacity to self organize and make decisions regarding task execution (Guzzo and Dickson, 1996; Buvik and Tkalich, 2022). The literature indicates that autonomy may be compromised in remote contexts due to increased documentation, supervisory control and weakened agile discipline. The process dimension comprises communication, roles and ceremonies, which represent the operational core of SCRUM. Communication supports coordination and knowledge exchange, roles define responsibilities of Product Owner, SCRUM Master and development team, and ceremonies sustain iterative inspection and adaptation cycles.

The outputs include engagement, trust and mutual support, which represent behavioral and attitudinal indicators of agile performance. Engagement reflects dedication, trust expresses expectations of competence and integrity and mutual support captures members' willingness to assist one another (Lindsjørn *et al*., 2016; Buvik and Tkalich, 2022). In Figure 2, autonomy influences all process and output factors, while process factors also affect outputs, following the logic of the I P O model. The relationship between trust and engagement is incorporated following Buvik and Tkalich (2022).

This structure highlights the relevance of comparing face-to-face and hybrid contexts, since SCRUM depends strongly on spontaneous interaction and ritualized collaboration. Understanding how these relationships change in the hybrid regime is essential to evaluating team performance. The hypothesis which guides the study examines whether relationships among the model's factors differ between face-to-face and hybrid periods and this hypothesis allow the identification of structural variations and shifts in specific performance indicators.

The instrument contained a section for respondent characterization and a section dedicated to measuring the constructs of the theoretical model. Statements followed a Likert scale from 1 to 5 and were phrased beginning with "My team..." to capture shared perceptions. The same items were answered twice to allow comparison between two

periods: the face-to-face phase, which ended in February 2020, and the hybrid phase after March 2023. Respondents belonged to the product engineering department of the defense division, comprising approximately 415 employees in 25 agile teams. Data collection occurred from May 14 to June 7, 2024, and only participants hired before March 2020 were considered to ensure valid evaluations of both periods.

A pilot test followed Forza's (2002) recommendations and involved six evaluators, including a researcher, a SCRUM specialist and four company professionals. The test resulted in terminology adjustments, removal of redundancies, improvement of clarity and exclusion of items that could compromise anonymity. The final dataset was analyzed using partial least squares structural equation modeling (PLS SEM), a technique suitable for models with several relationships, indicators from diverse sources and moderate samples.

Bootstrapping was used to assess coefficient significance and validate relationships. Multigroup analysis enabled comparison between face-to-face and hybrid results, directly addressing the research questions and hypotheses. This methodological approach provided a structured and reliable assessment of how the hybrid work regime influenced SCRUM practices and the performance factors analyzed.

4 Results

Descriptive results

The survey yielded 172 responses, of which 132 were validated after excluding participants who had not worked during the fully face-to-face period before COVID 19. This criterion ensured comparability between the two work regimes. The final sample exceeded the minimum statistical requirement indicated by G*Power®, which estimated 116 respondents as sufficient for the adopted parameters. Table 1 summarizes the respondents' profiles: 89 percent male, 73 percent team members, 17 percent SCRUM Masters, and smaller proportions of leaders and project managers. At the time of data collection, 95 percent worked in the hybrid model, and SCRUM or SCRUMban were the predominant methods. JIRA® appeared as the main tool used.

Table 1 – Characteristics of the interviewees

Gender	**Number**	**Percentage**
Male	118	89%
Women	14	11%
Role in the team		
Team Member	97	73%
SCRUM master	22	17%
Leader (supervisor or manager)	7	5%
Project Manager (DIP)	6	5%
Work regime		
Hybrid	126	95%
Remote	4	3%
Face-to-face	2	2%
Follows the company's working day		
Yes	129	98%
No	3	2%
Use SCRUM, SCRUMBAN, or OTHER		
SCRUM	76	58%
SCRUMBAN	51	39%
Other	5	4%
Which tool is used by the team		
MPI	8	6%
JIRA	115	87%
Other	9	7%
Has done SCRUM training		
Yes	46	35%
No	86	65%

Source: The authors

SCRUM knowledge was assessed through three indicators (Tables 2 to 4). Training data showed that although 35 percent reported participation in agile courses, only 25 percent had training directly aligned with SCRUM. Leaders had full alignment, while SCRUM Masters reached 41 percent and members 14 percent. Experience with agile methods averaged 6.2 years across the sample, with leaders reporting the highest mean. Self-assessed proficiency showed a median of 3 overall and 4 among leaders, SCRUM Masters and managers.

Table 2 – Respondents' level of knowledge in the SCRUM method

Have you done any training in SCRUM or agile methods?	**Number**	**Percentage**
Yes	46	35%*
No	86	65%*
Total respondents	**132**	
They answered that they had taken the SCRUM course	46	35%*
Has undergone training or is SCRUM certified or agile	33	72%*** (**25%***)
SCRUM master responders	**22**	
They answered that they had taken the SCRUM course	11	50%**
Has undergone training or is SCRUM certified or agile	9	82%*** (**41%****)
Respondent Project Manager	**6**	
They answered that they had taken the SCRUM course	3	50%**
Has undergone training or is SCRUM certified or agile	3	100%*** (**50%****)
Leader responders	**7**	
They answered that they had taken the SCRUM course	7	100%**
Has undergone training or is SCRUM certified or agile	7	**100%***
Responding team members	**97**	
They answered that they had taken the SCRUM course	25	26%**
Has undergone training or is SCRUM certified or agile	14	56%*** (**14%****)

Notes: * % in relation to the total number of respondents (132); ** % in relation to the total number of respondents in the same function in the team; % in relation to the total number of respondents in the same function who declared having done some training

Source: The authors

Table 3 – Use of respondents in the SCRUM method

How long have you been using agile methodologies (SCRUM or SCRUMBAN) in years?	**Minimum**	**Maximum**	**Average**	**Standard deviation**
Total respondents	1	15	6,2	3,2
SCRUM master	1	15	5,5	2,8
Project Manager	4	10	6,0	2,2
Leader	9	12	10,7	1,3
Team members	1	15	6,0	3,2

Source: The authors

Table 4 – Respondents' level of knowledge in the SCRUM method

I know the SCRUM method in depth/in detail	**Median**	**Standard deviation**
Total respondents	3	0,96
SCRUM master	4	0,95
Project Manager	4	0,82
Leader	4	0,46
Team members	3	0,94

Source: The authors

The use of roles, ceremonies and artifacts was evaluated through specific questionnaire blocks and cross checked with declared methodological adoption and tool usage, allowing triangulation with factors measured in the theoretical model (Tables 2 and 5 and Figure 2).

Measurement model

Before assessing the structural relationships, common method bias was examined with Harman's single factor procedure. The variance of 35.5 percent remained below the 50 percent threshold, indicating no substantial bias. A Confirmatory Composite Analysis was then conducted for the reflective constructs: autonomy, communication, roles, ceremonies, mutual support, trust and engagement, following established procedures for evaluating loadings, reliability, convergent and discriminant validity, as well as predictive and nomological validity (Hair *et al*., 2017; Hair Jr, Howard and Nitzl, 2020; Manley *et al*., 2021).

Table 5 presents external loadings, reliability coefficients and AVE for the face-to-face and hybrid periods. Items with loadings below 0.708 in the face-to-face dataset were removed to ensure convergence, while items slightly below the threshold in the hybrid period were retained because they did not reduce reliability. The list of excluded indicators is detailed in the text, and the resulting adjustments appear in Figure 2.

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Table 5 – Internal consistency, item loading, reliability and AVE before the pandemic and in-person work and after the pandemic and hybrid work

			Before the pandemic, and in-person work					After the pandemic and hybrid work					
	Código	p-value	Outer loading	CA	CR	AVE	R2	Outer loading	p-value	CA	CR	AVE	R2
Autonomy	AH1	<0.05	0.709	0.881	0.909	0.625		0.609	<0.05	0.824	0.871	0.532	
	AH2	<0.05	0.778					0.705	<0.05				
	AH3	<0.05	0.799					0.738	<0.05				
	AH4	<0.05	0.772					0.702	<0.05				
	AH5	<0.05	0.845					0.821	<0.05				
	AH6	<0.05	0.834					0.783	<0.05				
Trust	CH1	<0.05	0.919	0.881	0.909	0.625	0.441	0.849	<0.05	0.884	0.920	0.743	0.417
	CH2	<0.05	0.924					0.873	<0.05				
	CH4	<0.05	0.839					0.792	<0.05				
	CH5	<0.05	0.940					0.928	<0.05				
Engagement	EH1	<0.05	0.927	0.881	0.909	0.625	0.588	0.894	<0.05	0.823	0.896	0.742	0.539
	EH2	<0.05	0.926					0.915	<0.05				
	EH4	<0.05	0.850					0.768	<0.05				
Communication	OH1	<0.05	0.914	0.872	0.913	0.725	0.226	0.823	<0.05	0.796	0.868	0.625	0.336
	OH2	<0.05	0.887					0.849	<0.05				
	OH5	<0.05	0.850					0.813	<0.05				
	OH7	<0.05	0.747					0.663	<0.05				
Roles	PH11	<0.05	0.902	0.962	0.967	0.744	0.133	0.873	<0.05	0.938	0.947	0.643	0.315
	PH12	<0.05	0.887					0.789	<0.05				
	PH14	<0.05	0.882					0.793	<0.05				
	PH15	<0.05	0.884					0.831	<0.05				
	PH17	<0.05	0.899					0.783	<0.05				
	PH2	<0.05	0.755					0.761	<0.05				
	PH5	<0.05	0.792					0.699	<0.05				
	PH6	<0.05	0.884					0.861	<0.05				
	PH8	<0.05	0.860					0.800	<0.05				
	PH9	<0.05	0.869					0.813	<0.05				
Ceremonies	RH1	<0.05	0.760	0.899	0.921	0.624	0.120	0.642	<0.05	0.841	0.875	0.500	0.139
	RH11	<0.05	0.755					0.737	<0.05				
	RH13	<0.05	0.847					0.689	<0.05				
	RH15	<0.05	0.790					0.712	<0.05				
	RH2	<0.05	0.852					0.735	<0.05				
	RH4	<0.05	0.712					0.719	<0.05				
	RH5	<0.05	0.804					0.713	<0.05				
Mutual support	UH2	<0.05	0.897	0.885	0.929	0.813	0.626	0.883	<0.05	0.866	0.918	0.789	0.592
	UH3	<0.05	0.927					0.889	<0.05				
	UH4	<0.05	0.880					0.893	<0.05				

Source: The authors

Discriminant validity was confirmed using HTMT, with values below 0.85 in both periods. Predictive validity was supported through Q^2predict values above zero and comparisons between PLS SEM MAE and linear model MAE, which showed predominantly superior predictive performance.

Model invariance was tested with MICON, and the permutation results showed p values above 0.05 for all constructs, confirming configural and compositional invariance and allowing reliable multigroup comparison between the face-to-face and hybrid conditions.

Structural model (face-to-face x hybrid period)

In the face-to-face condition (Table 6), 10 of the 15 structural paths were significant. Engagement was positively associated with autonomy (β=0.392; p<0.001), trust (β=0.393; p<0.001) and roles (β=0.218; p=0.045), while ceremonies showed a negative effect (β=−0.204; p=0.009). Trust was shaped by communication (β=0.510; p<0.001) and autonomy (β=0.281; p=0.010), whereas mutual support depended strongly on communication (β=0.671; p<0.001). Autonomy also exerted consistent influence on all process factors and a subset of outputs, confirming its centrality in the face-to-face regime.

Table 6 – Influence test between variables (bootstrapping method) results for face-to-face work

Relationships	F2	Path Coefficient (beta)	Standard deviation	p-value	Result
Autonomy -> Mutual Support	0.025	0.111	0.066	0.092	Not significant
Autonomy -> Ceremonies	0.136	0.346	0.082	0.000	Significant
Autonomy -> Communication	0.293	0.476	0.081	0.000	Significant
Autonomy -> Confidence	0.107	0.281	0.109	0.010	Significant
Autonomy -> Engagement	0.255	0.392	0.084	0.000	Significant
Autonomy -> Roles	0.153	0.364	0.067	0.000	Significant
Ceremonies -> Mutual Support	0.000	-0.013	0.090	0.888	Not significant
Ceremonies -> Trust	0.000	-0.009	0.090	0.922	Not significant
Ceremonies -> Engagement	0.049	-0.204	0.078	0.009	Significant
Communication > Mutual Support	0.636	0.671	0.078	0.000	Significant
Communication -> Trust	0.246	0.510	0.114	0.000	Significant
Communication -> Engagement	0.006	0.073	0.117	0.531	Not significant
Trust -> Engagement	0.209	0.393	0.081	0.000	Significant
Roles -> Mutual Support	0.010	0.100	0.088	0.258	Not significant
Roles -> Trust	0.001	-0.036	0.115	0.753	Not significant
Roles -> Engagement	0.044	0.218	0.109	0.045	Significant

Source: The authors

In the hybrid period (Table 7), 8 of the 15 relationships remained significant. Engagement continued to depend on autonomy (β=0.525; p<0.001) and trust (β=0.235; p=0.003). Trust was again influenced by communication (β=0.488; p<0.001), and mutual support continued to rely on communication (β=0.503; p<0.001), with autonomy becoming an additional predictor (β=0.188; p=0.015). Autonomy maintained strong effects on process factors but no longer influenced trust (β=0.105; p=0.275). Roles and ceremonies, which had explained engagement in the face-to-face period, lost significance in the hybrid context.

Table 7 – Cross-variable influence test (bootstrapping method) results for hybrid work

Relationships	F2	Path Coefficient (beta)	Standard deviation	p-value	Result
Autonomy -> Mutual Support	0.051	0.188	0.077	0.015	Significant
Autonomy -> Ceremony	0.162	0.373	0.079	0.000	Significant
Autonomy -> Communication	0.507	0.580	0.064	0.000	Significant
Autonomy -> Confidence	0.011	0.105	0.096	0.275	Not significant
Autonomy -> Engagement	0.346	0.525	0.085	0.000	Significant
Autonomy -> Roles	0.460	0.561	0.054	0.000	Significant
Ceremony -> Mutual Support	0.009	0.084	0.084	0.318	Not significant
Ceremony -> Trust	0.007	0.091	0.085	0.286	Not significant
Ceremony -> Engagement	0.000	-0.005	0.107	0.966	Not significant
Communication > Mutual Support	0.344	0.503	0.104	0.000	Significant
Communication -> Trust	0.227	0.488	0.096	0.000	Significant
Communication -> Engagement	0.000	-0.002	0.114	0.985	Not significant
Trust -> Engagement	0.070	0.235	0.079	0.003	Significant
Roles -> Mutual Support	0.016	0.129	0.135	0.340	Not significant
Roles -> Trust	0.002	0.059	0.107	0.581	Not significant
Roles -> Engagement	0.010	0.110	0.111	0.320	Not significant

Source: The authors

Three comparative results stand out. First, several relationships remained stable across both regimes: autonomy → engagement, trust → engagement, communication → trust, and communication → mutual support. These stable paths indicate the persistence of key socioemotional and communication mechanisms in agile performance. Second, the relevance of roles and ceremonies for engagement weakened in the hybrid model, suggesting that the formal structure of SCRUM becomes less central to team motivation when interaction is distributed. Third, autonomy gained explanatory importance for mutual support only in the hybrid condition, possibly reflecting increased reliance on self directed coordination when physical proximity decreases.

Overall, the findings support the core relationships proposed in Figure 2, including the influence of autonomy on processes and outputs, the central role of communication in shaping trust and support, and the contribution of trust to engagement. Differences between regimes indicate a reduction in the explanatory power of formal SCRUM structures under hybrid work, while foundational socioemotional relationships remain stable.

Mult-Group Analysis (MGA)

To enable comparisons between the face-to-face and hybrid contexts, the study first verified measurement invariance. MICON results showed permutation p values above 0.05 for all constructs, confirming configural and compositional invariance and allowing the use of multigroup analysis. Examination of the coefficients reported in Tables 6 and 7 indicates two main empirical shifts between regimes. First, the effects of roles and ceremonies on

engagement, which were significant in the face-to-face period, became non-significant in the hybrid condition. This reduction suggests that formal SCRUM structures exert less influence on team attitudes when interactions are distributed. Second, autonomy no longer predicted trust in the hybrid period but became a predictor of mutual support, although it remained essential for processes and engagement in both work regimes.

These changes reflect adjustments in the internal dynamics of procedural and socioemotional constructs when the work arrangement shifts. At the same time, core relationships expected in the model, such as autonomy with engagement, communication with trust and mutual support, and trust with engagement, persisted across periods, indicating structural stability. It is noted that while MICON confirmed invariance and the tables present coefficients for each regime, this section does not report the specific p values from MGA for individual path differences. Thus, the differences highlighted here are based on descriptive comparison, with MGA serving as the formal test to determine whether the observed contrasts are statistically significant.

The findings show that the three output constructs of agile teams, engagement, trust and mutual support, remained stable when comparing face-to-face and hybrid work. Multigroup analyses performed on the structural paths (Table 8) indicated no statistically significant differences between the two periods.

Table 8 – Multi-group analysis to check the difference in factors

	Relationships	Path Face-to-Face Coefficient	Path Hybrid Coefficient	Difference	p-permutation value	Result
R1a	Autonomy -> Communication	0.476	0.580	-0.104	0.320	Not significant
R1b	Autonomy -> Engagement	0.392	0.525	-0.132	0.275	Not significant
R1c	Autonomy -> Confidence	0.281	0.105	0.177	0.279	Not significant
R1d	Autonomy -> Mutual Support	0.111	0.188	-0.077	0.428	Not significant
R1e	Autonomy -> Roles	0.364	0.561	-0.197	0.035	Significant
R1f	Autonomy -> Ceremony	0.346	0.373	-0.027	0.805	Not significant
R2a	Communication -> Engagement	0.073	-0.002	0.076	0.672	Not significant
R2b	Communication -> Trust	0.510	0.488	0.022	0.905	Not significant
R2c	Communication > Mutual Support	0.671	0.503	0.168	0.232	Not significant
R3a	Roles -> Engagement	0.218	0.110	0.107	0.514	Not significant
R3b	Roles -> Trust	-0.036	0.059	-0.095	0.564	Not significant
R3c	Roles -> Mutual Support	0.100	0.129	-0.029	0.853	Not significant
R4a	Ceremony -> Engagement	-0.204	-0.005	-0.200	0.150	Not significant
R4b	Ceremony -> Trust	-0.009	0.091	-0.100	0.428	Not significant
R4c	Ceremony -> Mutual Support	-0.013	0.084	-0.097	0.456	Not significant
R5	Trust -> Engagement	0.393	0.235	0.157	0.181	Not significant

Source: The authors

This observed stability can be partly explained by prior evidence reported by De Melo et al. (2013), who highlight communication as a mediating mechanism. In the study, communication continued to predict trust and mutual support across both regimes, suggesting that essential interaction flows were preserved despite reduced frequency in some communication items. A second explanation concerns autonomy, a core principle in SCRUM (SCRUM, 2017). Autonomy maintained significant influence on engagement and all process constructs, functioning as a compensatory mechanism for reduced physical proximity. A third foundation lies in the compositional invariance demonstrated by MICON, which confirmed that constructs were perceived equivalently across regimes, ensuring that the observed stability is not a measurement artifact.

These results partially align with prior literature. If autonomy and communication remain preserved, attitudinal stability is expected in agile teams (Kirkman and Rosen, 1999; De Melo *et al*., 2013). However, the findings diverge from traditional SCRUM expectations regarding the importance of roles and ceremonies. In the hybrid regime, both constructs lost explanatory power for engagement. Key responsibilities of the SCRUM Master also weakened, possibly linked to the limited formal training observed in the sample, where only 25 percent had validated Agile education and 41 percent of SCRUM Masters reported aligned training (Table 2).

Despite this decline, performance indicators did not decrease. The evidence suggests that the hybrid regime redistributes the influence of performance drivers: in face-to-face work, roles and ceremonies contributed more strongly to engagement, whereas in hybrid environments, autonomy and trust compensated for the loss of ritual structure. This interpretation aligns with structural results, such as the emergence of the autonomy → mutual support path in hybrid conditions, consistent with SCRUM's emphasis on continuous adaptation. Autonomy thus becomes even more central, acting as a behavioral pivot that sustains cohesion. The increased coefficient of autonomy → roles in the hybrid condition (Table 8) reinforces this idea.

However, stability should not be interpreted as an absence of risk. The deterioration of ceremonies and SCRUM Master responsibilities suggests partial execution of SCRUM in the hybrid regime. Reduced methodological rigor can compromise future delivery performance, even if attitudinal stability remains intact. This distinction is critical in industrial contexts such as product engineering, where interdependence and co located dynamics differ markedly from software environments. The study contributes by showing that as long as autonomy and communication remain strong, socioemotional performance can be preserved, even outside traditional software settings.

At the same time, the research highlights that hybrid arrangements may weaken the formal discipline of SCRUM while maintaining engagement and trust. This reveals a gap between methodological expectations and actual practice. The practical implications point to reinforcing training, strengthening roles, revitalizing ceremonies and clarifying communication processes. While autonomy and trust sustained performance in the short term, maintaining formal SCRUM practices is essential to ensure long term consistency and effectiveness of agile frameworks.

5 CONCLUSION

This study aimed to investigate how the transition from face-to-face work to a hybrid regime after the COVID 19 pandemic affected the performance of agile teams using the SCRUM framework in product engineering. The analysis examined whether the relationships among the factors that influence agile team performance changed across work regimes.

The findings indicate that most structural relationships remained stable when comparing the face-to-face and hybrid contexts. Multigroup analysis identified only one statistically significant difference, namely an increased influence of autonomy on roles in the hybrid regime (Table 8). This result suggests that, despite changes in the work arrangement, the core mechanisms that sustain agile performance were preserved, reinforcing autonomy as a central principle of SCRUM (SCRUM, 2017). Accordingly, the final model of significant relationships is valid across both regimes.

Overall, the results indicate that agile performance structures can remain robust under hybrid conditions provided that autonomy, communication and trust are sustained. However, the reduced relevance of formal roles and ceremonies highlights the need for methodological reinforcement to prevent long term erosion of SCRUM practices. Practical implications include strengthening SCRUM training, particularly for SCRUM Masters, reinforcing essential ceremonies and supporting team autonomy.

The study has limitations relies on retrospective self-reported comparisons, which introduces the risk of recall bias. The single company design limits generalizability, and the analysis does not include objective performance indicators such as delivery, quality or productivity. Future research should examine these relationships across multiple organizations, incorporate objective performance metrics and further advance theory by exploring boundary conditions of agile stability in hybrid settings.

Future research also should investigate links between SCRUM adoption and objective delivery outcomes, analyze the influence of members' knowledge levels and explore interactions with other management methods such as CCPM and Lean. The study contributes by demonstrating that agile performance can remain stable in hybrid arrangements, while emphasizing the importance of maintaining methodological rigor and reinforcing key SCRUM functions.

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