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Evaluación de la equidad en equipos ágiles utilizando análisis multimodal: un estudio exploratorio

Assessing Equity in Agile Teams Using Multimodal Analytics: An Exploratory Study

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Resumen: las metodologías ágiles han transformado el desarrollo de software al priorizar la colaboración y la adaptabilidad. Sin embargo, aspectos fundamentales como la diversidad, la equidad y la inclusión no suelen ocupar un lugar central en estos marcos. Esta omisión puede reforzar inadvertidamente desigualdades dentro de equipos diversos, en especial en entornos de trabajo híbridos. Este estudio aborda directamente esta problemática mediante el uso del análisis multimodal para explorar la relación entre la dinámica de interacción y la equidad percibida en equipos

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ágiles. A través de experimentos con estudiantes de ingeniería, los investigadores examinaron métricas como el tiempo de conversación y la dirección de la mirada, comparándolas con cuestionarios de equidad percibida. Los resultados mostraron correlaciones débiles, lo que sugiere que estas métricas cuantitativas por sí solas no son suficientes para comprender plenamente la equidad percibida. Este estudio aporta un valor significativo al debate sobre la inclusión en entornos ágiles y plantea la necesidad de complementar los indicadores cuantitativos para evaluar la dinámica colaborativa desde una perspectiva de equidad.

Palabras clave: Metodologías ágiles; evaluación de equidad; analítica multimodal.

Abstract: Agile methodologies have transformed software development by emphasizing collaboration and adaptability. However, important aspects like Diversity, Equity, and Inclusion are not usually central to these frameworks. This omission can unintentionally reinforce inequalities within diverse teams, especially in hybrid work settings. This study directly addresses this issue by using multimodal analysis to explore the relationship between interaction dynamics and perceived equity in agile teams. Through experiments with engineering students, researchers examined metrics such as speaking time and gaze direction, comparing these with perceived equity questionnaires. The results showed weak correlations, indicating that these quantitative metrics alone are not enough to fully understand perceived equity. This research makes a valuable contribution to creating more inclusive agile practices, advocating for the use of quantitative indicators to evaluate collaborative dynamics from an equity standpoint.

Keywords: Agile methodologies; equity evaluation; multimodal analytics.

I. Introduction

Agile methodologies have transformed the way software development teams operate, promoting flexibility, continuous collaboration, and iterative value delivery [1]. Among these, Scrum has gained prominence due to its simplicity and adaptability [2]. However, while agile principles emphasize collaboration, equity—understood as fair treatment and equitable distribution of opportunities—has not been a central aspect of their implementation [3].

The concept of equity in agile teams is particularly relevant given that interaction dynamics can influence how members perceive inclusion and fairness. Previous studies have noted that certain standard practices in agile methodologies could inadvertently exclude some members, especially in hybrid or diverse contexts [4, 5]. This raises a critical question: how can equity be measured and promoted in agile teams without compromising the principles of flexibility and adaptability?

Recent literature in software engineering has shown that development teams face significant challenges in terms of diversity, equity, and inclusion, which can directly affect the quality and design of technological products [6]. In the context of agile methodologies, current studies highlight the need to address dimensions such as workplace well-being and equity with greater depth, especially in diverse environments [7]. Furthermore, systematic reviews have identified that factors such as collaboration, sense of community, and egalitarianism are fundamental for agile teams to effectively manage uncertainty [8].

The analysis of speaking time and gaze enables the objective measurement of equity, as participants tend to look more at their teammates, especially when listening, which reveals patterns of inclusion and participation within the team [9].

Multimodal analytics provides an opportunity to address the analysis of interactions in work teams. Multimodal analytics combines data from diverse sources such as audio and video, offering a powerful tool for analyzing team interactions and extracting key equity indicators [10]. This approach enables the evaluation of speaking time and gaze dispersion, providing valuable information about interaction dynamics. For this purpose, advanced data processing and visualization tools were implemented [11].

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This work presents a non-experimental, correlational, and quantitative study that analyzes the relationship between interaction characteristics—specifically, speaking times and eye contact—with the perception of equity among participants in collaborative user story effort estimation activities. Its main contribution is to provide evidence about equity perception and its relationship with quantitative elements of interaction, with the potential to identify real-time behavioral indicators that may enhance or hinder equitable collaboration in work teams.

The specific objectives of this study are: (1) to identify relevant multimodal interaction metrics for evaluating equity in agile teams, (2) to analyze the relationship between verbal and non-verbal communication patterns with equity perception, and (3) to establish a methodological framework for the quantitative evaluation of equitable collaborative dynamics.

The main contributions of this work include: (i) the first systematic application of multimodal analytics to measure equity in agile teams, (ii) empirical evidence on the relationship between interaction metrics and equity perception, and (iii) a replicable methodological approach that integrates advanced audio and video processing techniques to evaluate group dynamics in collaborative contexts.

II. Background

Several studies have highlighted how agile methodologies promote collaboration but may not address equity issues. The Business Agility Institute indicates that despite the benefits of these methodologies, they do not explicitly address equity, potentially perpetuating inequalities in diverse teams or hybrid environments [12].

Research on gender and microinequities shows that women in software development face challenges such as being interrupted more frequently and receiving less recognition for their contributions [13]. Research on neurodiversity indicates that developers with conditions such as autism spectrum disorder (ASD) or attention deficit hyperactivity disorder (ADHD) face unique challenges in agile environments due to difficulties with executive functions [14].

A systematic literature review highlights that while diversity is well-researched, equity and inclusion have not received the same level of attention in agile teams [15]. Additionally, Hernández *et al.* identified metrics for measuring productivity in agile teams but noted the lack of metrics for evaluating qualitative aspects such as within-team collaboration [14].

These findings suggest that multimodal analytics technology, combined with productivity metrics, can be a valuable tool for identifying and addressing imbalances in team dynamics, contributing to a more holistic approach for improving equity in agile environments. The analysis of metrics such as speaking time and gaze direction allows for quantifying member participation in group interaction, providing objective indicators for studying equity and inclusion in work teams [9, 10].

Table 1. Comparison with previous studies

Study	Methodology	Evaluated Metrics	Context	Limitations
Hyrynsalmi et al. [6]	Systematic collaborative discussion	Key themes on diversity and inclusion in software development (SDDI)	Software development teams	Qualitative approach, no quantitative metrics
Damian et al. [7]	Best practices review	Organizational diversity, equity, and inclusion (DEI) strategies	Software industry	Conceptual framework, no empirical validation
Anifa et al. [8]	Systematic review	Effectiveness of agile methodologies	Multiple industries	Not focused on equity
Riquelme et al. [10]	Multimodal social networks	Social network interactions	Discussion groups	No equity measurement

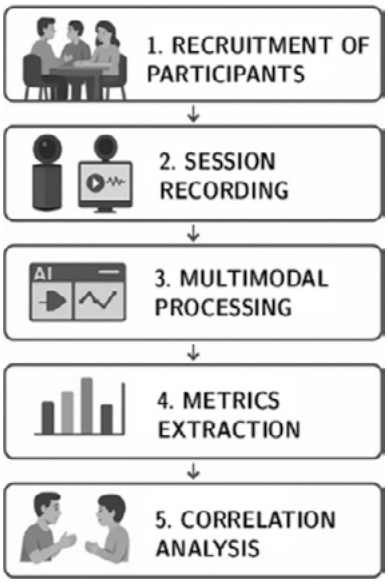
This study	Multimodal analytics + surveys	Speaking time, gaze direction, equity perception	Specific agile teams	Limited student sample

Note: author´s source

III. Method

The study methodology followed a systematic five-stage approach that integrates multimodal analytics techniques to evaluate equity in agile teams. Figure 1 illustrates the complete flow of the methodological process, from recruitment to final statistical analysis.

Figure 1. Methodological workflow in five stages: (1) Recruitment - 41 Computer Engineering students in teams of 4 with knowledge in agile methodologies; (2) Capture - recording with 360° camera and omnidirectional microphone during planning poker sessions (≤10 min); (3) Multimodal processing - audio analysis with WhisperX and video with OpenCV+MediaPipe for eye tracking; (4) Metrics extraction - automated calculation of speaking time, gaze and eye contact with Z-score normalization by group; (5) Correlation analysis - equity perception surveys (11 questions) and correlation calculation



Note: generated with the assistance of ChatGPT (OpenAI, 2025).

This methodological approach enables the objective and automated capture of equity indicators through integrated analysis of verbal and non-verbal communication patterns during collaborative activities representative of professional agile environments.

3.1 Study type and activities performed by subjects

A quantitative, non-experimental, and correlational study was conducted, where subjects participated in collaborative user story effort estimation activities. Each team performed an in-person group session, with discussion and joint agreement, simulating real practices of agile methodologies.

The experimental configuration considered team size, fixed at four members per group; meeting duration, limited to a maximum of 10 minutes; and physical environment, which was controlled through strategic positioning of participants. Participants were required to reach consensus on story point estimation for a predefined set of user stories, replicating the typical dynamics of agile planning ceremonies.

3.2 Variables and measurements

Equity Perception: Measured through a validated 11-question survey based on the "Diversity, Equity, and Inclusion for Agile Teams Assessment" questionnaire from Comparative Agility [15]. Questions evaluated using a 5-point Likert scale:

1. We understand how decisions that impact team equity are made.
2. People from all backgrounds have equal opportunities to succeed.
3. When relevant, we question others' assumptions about factors that affect equity (race, age, gender identity, ethnicity, sexual orientation, ability, etc.).

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4. We adjust our mindset and attitudes when we have new experiences that challenge our previous beliefs.

5. Our team members actively engage in self-reflection to identify and address personal biases.

6. When we become aware of our personal biases, we adopt tactics to manage them.

7. When a concern about workplace equity arises, we take action.

8. When a concern about workplace equity arises, I feel comfortable discussing it with my colleagues.

9. We prioritize eliminating barriers that prevent equity.

10. ur team members actively identify and address how privilege within the team impacts equity.

11. Decisions are fair and everyone is treated with equal importance.

Interaction Metrics - Speaking Time: the isSpeaking variable captures the total duration that each participant maintains vocal activity during the group session, which can be interpreted as an indicator of verbal participation and communicative dominance in the collaborative context. It is calculated using WhisperX for automatic speech recognition, filtering environmental noise.

Interaction Metrics - Gaze Direction: the inDistance variable measures the accumulated duration that each participant directs their gaze toward other members when they are in close interpersonal proximity (less than 1.2 meters), representing moments of focused visual attention associated with active listening. This metric is obtained through OpenCV and MediaPipe for facial and eye tracking, detecting gaze direction vectors. There is evidence that eye contact between team members provides information, regulates interaction, expresses intimacy, influences social control, and facilitates service goals and tasks, contributing to collaboration [16].

Additionally, the count variable tallies the total number of discrete episodes of eye contact between participants, interpreted as an indicator of the frequency of non-verbal communicative exchanges. Complementarily, the inDistanceSpeaking variable combines vocal activity with eye contact in close proximity, capturing the synchronization between verbal and non-verbal communication as an indicator of deep interpersonal engagement. It is calculated as the temporal intersection between speaking periods and moments of gaze directed at nearby participants.

Finally, the mutualObservation variable quantifies periods of bidirectional eye contact between pairs of participants, representing moments of shared attention associated with greater coordination.

Group Normalization: to control for differences in interaction dynamics specific to each team, Z-score normalization by group was applied to both equity perception metrics and temporal interaction variables. This method standardizes each individual value relative to the mean and standard deviation of their specific team, allowing analysis of relative participation patterns within the particular context of each group. Group normalization is especially relevant for identifying intra-team equity dynamics, as it controls for the inherent characteristics of each group and reveals differences in relative participation that might remain hidden when analyzing only absolute values.

3.3. Selection

The participants were Civil Computer Engineering students from the University of Valparaíso who had previously taken courses related to agile methodologies. The study received approval from the institutional ethics committee (CEC-UV 236-21).

The study included 41 students organized into teams of four members each, with five women (12%) and 36 men (88%). Teams were formed randomly without segregating by gender or academic experience. Inclusion criteria were: currently taking or having taken software engineering courses with content on agile methodologies, availability to participate in 10-minute in-person sessions, and informed consent for audiovisual recording. Exclusion criteria included hearing or visual difficulties that could interfere with participation in group activities.

3.4 Data collection techniques

Audiovisual Capture of Interactions: A Kandao Meeting Pro 360 camera with omnidirectional microphone was used to record group interactions.

Automatic Speech Recognition: WhisperX was implemented, an automatic speech recognition system developed by OpenAI that uses transformer architectures for accurate transcription and temporal segmentation.

Computer Vision Analysis: OpenCV was employed in combination with MediaPipe for automated analysis of facial movements and eye tracking.

Bidirectional Eye Contact Detection: A custom algorithm based on camera angle projections was developed, avoiding Rodrigues rotation to calculate direction vectors and temporal anti-noise filtering [19].

Equity Perception Survey: A validated questionnaire based on Likert scales developed specifically for collaborative work contexts was applied. The survey incorporates equity dimensions previously validated in literature on diversity and inclusion in work teams [15].

3.5 Metric calculation

The quantitative metrics were calculated using the following formulas:

Coefficient of variation (CV%):

$$CV\% = (\sigma / \mu) \times 100 \qquad (1)$$

Where σ is the standard deviation and μ is the mean of the variable.

Z-score normalization by group:

$$Z = (x - \mu\_group) / \sigma\_group \qquad (2)$$

Where x is the individual value, μ_group is the group mean, and σ_group is the group standard deviation.

Average equity perception:

$$AEaverage = \Sigma(responses\_i) / n \qquad (3)$$

Where responses_i are the Likert scores (1-5) for each question and n = 11 questions.

IV. Results

The descriptive statistical analysis of the main study variables is presented in Table 2. The data reveal considerable variability in interaction metrics among participants. Speaking time showed the highest relative variability (CV = 45.4%), followed by gaze time (CV = 35.0%), while equity perception presented lower dispersion (CV = 12.6%), indicating greater consensus in participant evaluations.

The distribution of speaking time (M = 1822.54 seconds, SD = 826.91) evidences substantial differences in verbal participation, with some participants speaking up to 6.9 times more than others (range: 556-3822 seconds). Gaze time toward other members (M = 5347.83 seconds, SD = 1873.97) also showed wide variation, reflecting different patterns of visual attention during group interactions. Equity perception (M = 4.14, SD = 0.52) was situated above the midpoint of the scale (2.5), suggesting a generally positive evaluation of the collaborative environment, although with notable individual variations.

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Table 2. Descriptive statistics of study variables. SD = Standard Deviation; P25 = 25th Percentile; P75 = 75th Percentile; CV% = Coefficient of Variation. Equity perception was measured on a 1-5 point Likert scale

Variable	N	Mean	SD	Min	Máx	Median	P25	P75	CV%
Speaking time (sec)	41	1822.54	826.91	556.0	3822.0	1703.00	1138.00	2503.00	45.4
Gaze Time (sec)	41	5347.83	1873.97	1959.0	8708.0	5186.00	3928.00	7063.00	35.0
Equity Perception	41	4.14	0.52	2.8	5.0	4.18	3.91	4.45	12.6

Note: author´s source

4.1 Correlation analysis

To explore the relationship between speaking and gaze times and average equity perception, the Pearson correlation coefficient was used. This statistical technique evaluates the strength and direction of a linear relationship between two quantitative variables, providing a coefficient (r) that varies between -1 and 1. A value close to 1 or -1 indicates a strong linear relationship, while a value close to 0 suggests that there is no significant linear relationship. Additionally, the associated p-value was calculated to determine the statistical significance of the results, considering $p < 0.05$ as the threshold for significance.

Table 3. Correlations between interaction metrics and equity perception

Metric	Correlation (r)	p-value	Significance
Speaking Time	0.123	0.444	Not significant
Gaze Time	0.082	0.612	Not significant
Speaking time (normalized)*	-0.326	0.043	Significant
Gaze Time (normalized)*	-0.191	0.244	Not significant
* Z-score normalization by group			

Note: author´s source

The results indicate that the quantitative interaction metrics analyzed without normalization do not show a statistically significant relationship with participants' equity perception. However, when group normalization is applied, a significant negative correlation emerges for speaking time.

4.2 Analysis of verbal metrics

The analysis of speaking time revealed a statistically significant negative correlation with equity perception ($r = -0.326$, $p = 0.043$) when group normalization was used. This verbal metric showed the strongest relationship with perceived equity, suggesting that participants who speak proportionally more within their teams tend to perceive lower equity. The distribution of speaking time varied considerably between teams, with coefficients of variation ranging from 0.23 to 0.67.

4.3 Analysis of visual metrics

The metrics related to gaze direction showed distinct patterns. The inDistance variable (gaze time toward other members) presented a weak and non-significant correlation ($r = -0.191$, $p = 0.244$). However, the count metric (eye contact episodes) showed the weakest correlation of all analyzed variables ($r = -0.050$, $p = 0.761$), indicating that the frequency of visual contacts is not related to equity perception.

4.4 Analysis of combined metrics

The inDistanceSpeaking metric, which combines vocal activity with eye contact in close proximity, showed a pattern similar to pure speaking time, with a negative correlation near statistical significance (r = -0.305, p = 0.059). This suggests that verbal dynamics have greater weight than visual ones in equity perception. The mutualObservation variable (bidirectional eye contact) showed a weak correlation (r = -0.183, p = 0.265).

Figure 2. Relationship between group-normalized speaking time and equity perception. Points represent individual participants, where each color indicates a different team

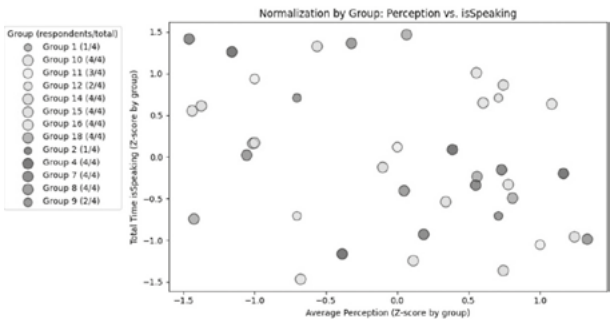

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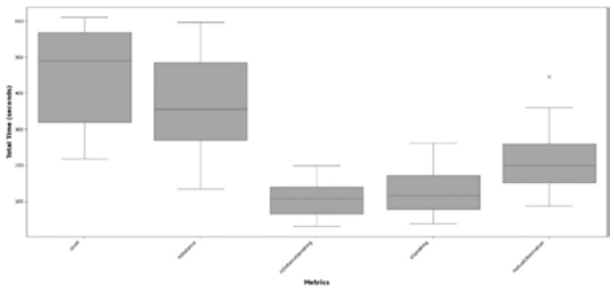
Figure 3. Comparative boxplots showing the distribution of total time (in seconds) for five key group interaction metrics



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V. Discussion

Our results confirm that, although agile methodologies promote collaboration, the observed interaction dynamics have a complex relationship with equity perceptions, coinciding with studies that suggest these methodologies do not explicitly address equity [12].

The most relevant finding is the significant negative correlation between normalized speaking time and equity perception. This counterintuitive relationship finds support in the literature on group dynamics. Keltner *et al.* (2003) describe the "power paradox," where those who exercise greater verbal influence become more sensitive to system inequities [17]. Similarly, studies on "mental load" show that members with disproportionate communicative responsibilities develop greater awareness of imbalances in task distribution [18].

In our context, participants who speak more might be perceiving that they invest greater communicative effort without receiving equivalent contributions, reflecting a compensatory effort in response to perceived lack of equity or the feeling of assuming a disproportionate burden. The similar correlation in inDistanceSpeaking suggests that verbal dynamics combined with eye contact are more sensitive indicators of equity perception than passive observable behaviors.

The study limitations include the small sample size of students that limits generalization to professional contexts, the controlled experimental environment that does not fully reflect the real dynamics of agile teams, and the exclusive focus on quantitative metrics without qualitative analysis of interaction content. A critical limitation of this study is the marked gender imbalance in the sample (88% men, 12% women). In a study about equity, this disproportion is particularly problematic because: (1) it may not reflect the real dynamics of diverse teams, (2) it limits the ability to analyze gender differences in equity perception, and (3) it may bias results toward predominantly masculine perspectives. Future research requires more balanced samples to obtain valid conclusions about equity in diverse teams.

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Team-normalized verbal interaction metrics can serve as early indicators of imbalances, allowing timely interventions before they become consolidated. Equitable practices should focus not only on speaking time distribution, but on the quality of interactions and the perceived value of contributions. The integration of real-time multimodal analytics tools could provide immediate feedback on interaction dynamics, facilitating self-regulation and the development of more equitable collaborative behaviors, although their implementation must be ethical and transparent.

VI. Threats to validity

This study presents several threats to validity that must be considered when interpreting the results. In terms of internal validity, the controlled experimental environment may not fully reflect the real dynamics of professional agile teams, limiting the generalization of findings. External validity is compromised by the limited sample size (41 participants) and demographic bias (88% men), which prevents gender analysis and limits population representativeness. Regarding construct validity, speaking time and gaze metrics may not fully capture the multidimensional complexity of perceived equity. Finally, statistical validity may be affected by limited statistical power due to sample size, requiring cautious interpretation of non-significant results.

VII. Conclusions

This study achieved its initially proposed specific objectives: (1) it successfully determined a set of indicators to measure equity in agile collaborative environments, identifying speaking time and gaze time as quantifiable metrics through multimodal analytics; (2) it implemented these metrics in the workflow through the integration of audio (WhisperX) and video (OpenCV/MediaPipe) processing tools, achieving automated capture and analysis of interactions; and (3) it evaluated the results through statistical analyses that revealed a significant negative correlation between normalized speaking time and equity perception ($r = -0.326$, $p = 0.043$), partially validating the study's initial hypothesis.

This study explored in depth the relationship between interaction dynamics in agile teams and equity perception using multimodal analytics. The main finding confirmed a significant negative correlation between normalized speaking time and equity perception, indicating that those who speak proportionally more within their teams tend to perceive a less equitable environment.

The results highlight that, although simple quantitative metrics such as speaking time can provide valuable information, these must be interpreted in the specific context of each group to reveal significant relationships. Group normalization proved essential for identifying patterns that would otherwise remain hidden in raw data.

Our findings contribute to the understanding of how equity can be measured and promoted in agile teams, suggesting that monitoring speaking patterns, especially when analyzed in relation to each specific team's dynamics, can serve as an early indicator of possible imbalances in participation.

The main limitations of this study include the reduced sample size, gender imbalance, and an exclusively academic context. The focus on quantitative metrics, while valuable, should be complemented with qualitative analyses of interaction content. Future work should expand the sample to diverse professional teams, incorporate additional variables such as speech quality and emotional dynamics, and develop predictive models through machine learning. The integration of real-time monitoring tools for immediate feedback represents a promising direction for practical applications in real agile environments.

VIII. Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used Claude and Grammarly Editor to improve readability and language. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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