Exploring socioemotional skills and their effects on children's social interactions in multiplayer video games

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Socioemotional skills are increasingly being recognized as important for the development of children's social relationships and positive life outcomes. The relation between socioemotional skills and social life outcomes has mainly been studied through self-report measures of socioemotional skills and the quality of social interactions. However, the relation between socioemotional skills and real-time social interactions within digital contexts, where many social experiences now take place, has received considerably less attention. In the present study we explore how children's socioemotional skills are related to real-time verbal communication within an online multiplayer video game context. To this end we recorded and annotated multiplayer gameplay sessions of the applied gaming intervention Ruby's Mission. The results revealed a small positive relation between a child's socioemotional skills and their proportion of overlapping social interactions. Other factors also correlated to children's social interaction. Personality scores showed a small negative association with children's proportion of responses. Social familiarity revealed small positive effects for proportions of speech and proportion of responses. Furthermore, group size showed medium effects for the number of overlapping social interactions. Finally, asynchronous player roles showed a large effect, where children who were assigned the driver role had significantly larger proportions of responses.

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These insights may be insightful for understanding how socioemotional skills relate to real-time social interactions in online multiplayer video game environments.

CCS Concepts: • **Human-centered computing** → **Empirical studies in collaborative and social computing**; *Computer supported cooperative work*; • **Applied computing** → *Computer games*; Psychology.

Additional Key Words and Phrases: Real-time social interaction, verbal communication, socioemotional skills, multiplayer video gaming, applied games

1 Introduction

Socioemotional skills are increasingly being recognized as important for the healthy development of children, and have been associated with positive life outcomes, such as enhanced benefits from tertiary education, social outcomes, subjective well-being, and general health [42]. The relation between socioemotional skills and social interactions has mainly been studied by relating socioemotional skills with self-report measures of the quality of social interactions, as perceived by self and others. For example, a positive relation was found between emotional intelligence and the quality of social interactions, as perceived by self and others [34]. Emotional intelligence was also found to be predictive of conflict management skills [57]. Individuals who scored higher on emotion regulation abilities reported higher scores for being interpersonally sensitive, more prosocial, and they were viewed more positively by peers [35].

"Socioemotional skills" is an umbrella definition for people's abilities to recognize emotions in oneself and others, and skills for navigating the social environment [17, 22, 32]. Many different constructs within the social, and emotional domains fall (at least partially) under this umbrella definition. Emotional intelligence, for example, includes the abilities to accurately perceive emotions, access and generate emotions to assist thought processes, understand emotions and emotional knowledge, and regulate emotions reflectively to foster both emotional and intellectual growth [51]. Another construct is the 5-factor model for social and emotional learning (SEL). This model includes 5 core competencies which are self-awareness, self-management, social awareness, relationship skills, and responsible decision making [26]. Furthermore, social competence, describes a set of skills related to empathy, communication, emotion regulation, social problem solving, and social encoding [28]. For the remainder of this study we define socioemotional skills as in Alexandridis et al. [2], namely the ability to: (1) *recognize emotions in one-self and in others*, (2) *understand the meanings of emotions to guide thinking and doing*, and (3) *understand the subjectivity of emotional experiences*.

Most studies on socioemotional skills and social interaction have used questionnaires and self-report measures, where socioemotional skills are conceptualized as a individual and stable trait which are then related to various social and life outcomes. Yet, the effects of socioemotional skills on real-time social interaction, that is socially interactive behavior as it unfolds in social situations, has received considerably less attention from researchers [8, 20]. In fact, little is known about the impact of socioemotional skills on processes of social interaction, and how these are then related to positive life outcomes. Investigating how socioemotional skills are expressed through real-time social interaction, may thus provide an important focus of study to provide more insights about how socioemotional skills play into people's positive social and life outcomes [12, 20].

It is important to have a good understanding of social interactions, as mutually engaging (peer) interactions play an important role in the development of socioemotional skills in children. Through interactions with others, especially more socially skilled individuals, a child may improve their social and emotional abilities [49], as others provide feedback on what is and what is not appropriate social behaviour [61]. This is reflected in Junge et al.'s (2020) developmental model of social competence, which emphasizes the significant influence of the various contexts in which children practice and learn social competence. Similarly, Goodman [22] describes how interactions with familiar adults and interactions with peers are fundamental for development of socioemotional skills. Although the relationship between socioemotional skills and social interactions is reciprocal, where social

interactions also shape the development of socioemotional skills, our study focuses on how current socioemotional skills translate to children's real-time social interactive behavior. This enables us to investigate this relationship independently of the broader question of how social interactions contribute to the development of socioemotional skills.

1.1 Social Interactions in the Digital Domain

In recent decades, social interactions have increasingly moved into the digital world of social media, online communication, and online video games[1]. Social media use and the use of online video games in youth has seen a substantial increase in recent years [10]. One-in-six primary school students in the Netherlands indicate to have intensive (almost all-day) online contact with others via social media. This occurs almost twice as often among secondary school students (one-in-three) [10]. Furthermore, 75% and 89% of youth in primary (4 to 12 years old) and secondary (12 to 16 years old) education, respectively, play (online) video games according to national prevalence estimates in the Netherlands [48].

In line with research that considers real-world play experiences as instrumental for developing socioemotional skills [24], one may observe that also video games can potentially provide children with a safe and engaging environment in which to practice and improve their socioemotional skills. Indeed, playing video games may have a positive effect on social, emotional, and cognitive development [9, 23]. For example, playing prosocial video games, games where characters help and support each other, may increase both short-term and long-term prosocial behaviour in real-life settings [21, 56]. It was also positively related to cooperation, sharing, empathy, and overall positive relationships [27], and may even decrease aggressive cognitions [25]. Furthermore, numerous applied gaming interventions have been developed in recent years specifically aimed at training socioemotional skills [2, 15, 18, 52, 59]. It shows that video games hold great potential for improving children's socioemotional skills through applied gaming interventions.

Despite the potential benefits of video games, the potential negative effects on socioemotional development have also been investigated. Many studies found increased levels in aggressive cognitions as a result of playing violent video games [4, 13]. Moreover, playing violent video games has been linked to reduced empathy and a decreased likelihood of engaging in prosocial behaviour [14]. A small negative effect was also discovered between online video game use and emotional competence (i.e., positive emotion, emotional expression, and emotional intelligence). This effect was found to be larger for video game users with a high risk for internet gaming addiction [55].

Children's socioemotional skills are often developed and practiced through interactions with peers [28, 49, 61]. Given that social interactions between peers increasingly occur in digital spaces, such in online video games and social media platforms [10, 48], these platforms become more important as a social context for children to develop and practice their socioemotional skills. However, in order to assess how such online platforms may impact sociocognitive development, and how social communicative behavior is expressed, we wanted to first investigate how self-reported measures of socioemotional skills in children actually relate to online social behavior. To our knowledge, previous studies have seldom addressed this relation directly, and we aim to do so by combining objective measures of social behavior and communication with children's self-reported socioemotional skills. Moreover, social group dynamics are highly context-dependent and are shaped by complex interactions between both individual factors (e.g., personality, socioemotional skills) and group factors (e.g., group size, familiarity). We therefore focused specifically on these variables to predict real time-social communication in video games. Finally, from a game design perspective, we were specifically interested in how specific dynamics of the game (e.g., goals,

[1]The recent COVID-19 pandemic also contributed to social interactions moving more to the digital domain. For example, due to the pandemic, all levels of education required to implement digital communication tools (e.g., Microsoft Teams or Zoom) in class, increasing social interaction through digital means.

tasks, player roles) influence patterns of children's social behavior and communication in multi-party online video games.

1.2 Contributions

This paper contributes to the understanding of the interplay between socioemotional skills and social interactions within the context of online multiplayer video games. Specifically, our contributions are:

- Empirically grounded insights between the relation of socioemotional skills, personality, and context-related factors and social interaction in online multiplayer video game contexts;
- Extends earlier work by comparing questionnaire data on socioemotional skills to observed real-time social interactions.
- An interdisciplinary approach on combining psychology and game design to study social interactions in online multiplayer video games.

One methodological challenge to achieve these contributions was to operationalize real-time social behaviour in an online video game environment. We chose to create a stimulus-response based model from a pragmatic perspective, focusing on verbal communication patterns (e.g., speech utterances). This model was grounded in empirical observations drawn directly from game recordings and validated through comparison across multiple annotators.

A second challenge involved capturing the relevant context of these social interactions to ensure our study design was representative for the children. Rather than bringing children to a laboratory setting, we brought conducted the experiments at the schools of the participants, which ensured more familiar social environment. Furthermore, the choice of the game *Ruby's Mission* was deliberate, as it is specifically designed to stimulate verbal interaction, and deals with topics of emotional expression. Also, because Ruby's Mission gameplay lacks the digital communication tools (e.g. pinging) common in other games, we were able to more effectively isolate verbal communication and minimize the risk of missing social interactions that might otherwise occur through unrecorded non-verbal channels

The remainder of this paper is organized as follows. Section 2 outlines methodological approaches to studying social interactions and how they are applied within the context of the online multiplayer game. Section 3 details the research methodology, including participant demographics, a description of the Ruby's Mission game, the data collection procedures, and the framework used for annotation and statistical analysis. Section 4 presents the results of the multi-level analyses, divided into observations from the total game session, the mini-games, and the cooperative sections specifically. Section 5 until 7 provides a discussion of results, and finally we briefly discuss the limitations and future directions for this research

2 Approaches to Studying Social Interactions and Their Application to Communication in an Online Multiplayer Video Game

In the present study, we conceptualize social interactions as coordinated and reciprocal patterns of behaviour between multiple individuals. We are especially interested in how socioemotional skills are related to immediate observable social behaviors, e.g., speech utterances in verbal communication, and how these are expressed in an online multiplayer video game for children. In humans, social interactions generally consist of both verbal and nonverbal behaviours, including speech acts, vocalizations, eye contact, facial displays, gestures, and other bodily movements that together facilitate and regulate interpersonal communication [7, 19, 29, 33]. Additionally, video games may introduce new ways of non-verbal communication such as pinging [31] .

In the current study, we will specifically focus on verbal communication during an online multiplayer video game. We will investigate how children communicate with one another while carrying out several tasks and assignments related to socioemotional skills in the game Ruby's Mission [2], a multiplayer video game context

where children complete various cooperative tasks. Ruby's Mission's design enables us to specifically focus on verbal communication because the game does not include specific in-game communicative tools (e.g. pinging). The online context eliminates other non-verbal communication cues such as eye contact. Before we describe our specific research goals, we first provide a brief outline of the methodological approaches to study (verbal) social interaction that we will use. Next, we will briefly outline how we intend to apply these approaches in the context of a multiplayer online video game for children.

One general approach in interaction research has been to characterize social interactions according to different types of sequentially structured stimulus-response (SR-)models, in which every social action (e.g. speech utterance) is determined by the previous action of another person [5, 19]. This approach allows researchers to describe, classify, and organize different 'interaction events', their sequence, structure and intent, in a systematic fashion. An example of this can be found in research literature on turn-taking systems in conversational interaction [50, 62]. The focus here is on the (micro) dynamics of person-to-person or small group conversations (e.g., frequency and duration of speaking turns and gaps between turns), as well as their structure and organization. This is also referred to as conversation analysis [29]. Similarly, in our study we will mainly use recordings of verbal exchanges between children as a means to quantify patterns of social interaction while they are engaged in an online multiplayer video game.

The aim of the present study is to develop a theoretical understanding of how children's socioemotional skills influence their verbal communication within an online multiplayer video game. To this end we use a similar approach to the Ethnomethodological and Conversation-analytical (EMCA) perspective [44]. The EMCA approach focuses on the ways in which social actions are structured, organized and made meaningful by the participants themselves. It emphasizes a bottom-up approach that makes use of interactional resources like talk and bodily conduct to make sense of their actions in real time. EMCA employs naturalistic data, such as audio and video recordings, to analyze moment-by-moment practices, avoiding post hoc descriptions.

2.1 Present Study

In this first explorative study of the relation between socioemotional skills and online video game interaction in children, we adopt a combined methodological approach that integrates the SR-approach with an EMCA perspective. We make use of a custom, basic SR-framework (see Section 3.5) to classify verbal social interaction within an online video game context. To develop this framework we examine naturalistic data (i.e., video- and audio recordings of the play sessions) in a bottom-up approach to identify recurring types of SR-interactions that are related to our specific context, thereby grounding our SR-model in empirical data. Verbal social interaction is then operationalized through four different, but closely related measure, based on the analysis using this tailor SR-model.

First we investigate the *proportions of speech* that a person is speaking while playing the game. This measure provides a general indication of a person's overall participation in group interaction during video game play.

Second, we will use the *frequency of speech acts* exhibited by each player while playing the game, as a measure of how many times a person engaged in an act of social interaction, regardless of its duration.

Third, we will use the *proportion of responses* for every participant. The SR-model classifies a response as any type of interaction that is determined by the action of the previous person [5]. Within strictly verbal social communication, this means that any verbal speech act that is made as a result of a previous speech act can be classified as a response. As such, in this study we assume that each response is part of a conversation between at least two persons. This measure provides an indication of how much of a person's social interaction was spend in conversation with others.

Finally, we compute *overlapping speech acts*. The overlap in this study can be considered as a measure of the frequency with which a person instigates an error within social interaction. In the literature on turn-taking and

Fig. 1. Screen captures from the video game Ruby's Mission. **Left:** First person view during the navigation phase. The text on the wall is one of the collectable graffiti tags. In the distance we can see a character with a blue indicator above them. This is the start of a scenario game. **Right:** A screenshot from the cooperative part of the graffiti game. In this part of the game, the player can see what each other player (and themselves) have answered during the individual section. They can now discuss which texts they want to pass as an answer to the game.

conversation analysis, overlap in speech is considered erroneous [50] and requires a resolving mechanism by speakers [53]. This measure is especially interesting, as it may consider overlapping speech episodes as a sign of erroneous interaction, possibly related to one's socioemotional skills.

Previous studies have identified correlations between questionnaire-based measures of socioemotional skills and social interactions [42]. Consequently, we anticipate that children's socioemotional skills will be associated with their real-time social interactions. However, given the limited understanding of how socioemotional skills relate to observable interactive behavior, this study remains exploratory.

3 Methodology

3.1 Participants

Students from grades 7 and 8 (typically nine to twelve years of age) from various Dutch elementary schools were recruited for participation in the present study. Schools were approached through an event where students training to become elementary school teachers were introduced to scientific researchers. The first author participated in this event and obtained permission to contact the students for the purpose of recruiting the schools where they were teaching. The schools that agreed to participate, were asked to send an information letter and informed consent letters to the parents of their students through their habitual way of communication (i.e., per e-mail, as a hand-out, or through school-specific digital platforms). Only the students whose parents signed the informed consent letters were eligible to participate in the experiments.

3.2 Ruby's Mission

The video game used for the experiments was Ruby's Mission[2] (Figure 1) [2]. Ruby's Mission is an applied video game that is aimed at improving socioemotional skills in children aged eight to twelve years old. It is a cooperative online multiplayer video game that is played by three or four children together. In the game the players meet a robot named Ruby, who asks them to help Ruby learn about emotions. Three different types of mini-games were designed for the players to practice their socioemotional skills. Each focused on encouraging players to reflect on their own emotions and share their reflections with others to decide on an appropriate answer.

[2]For an elaborate overview of the game design of Ruby's Mission, we refer the reader to [2].

The video game can be subdivided into two main phases that alternate until the game is finished: (1) one parts consists of navigating Ruby through the 3D game world to the various starting points of the mini-games. While navigating through the game world, the players must collect graffiti tags by clicking on them that are scattered throughout the buildings in the game world. The other phase (2) consists of playing one of three type of mini-games; graffiti game, scenario game, or the poster game. A single level contains multiple mini-games of the same types centered around different emotions. Each mini-game can be subdivided into an individual part and a cooperative part. In the individual part the players are tasked to provide an answer individually to the task on screen. This part is typically related to reflecting on your own emotions. The cooperative part requires the players to share their answers from the individual part, such that they may find an answer as a group to the task at hand. Both parts are played cooperatively with all participating players.

Asynchronous player roles, roles with unique abilities, are assigned randomly to the players in Ruby's Mission at the start of a level. Cooperation between the players is stimulated as each player role is essential to finishing the game. A player is assigned one of three roles: (1) driver, (2) decider, or (3) collector. The driver is responsible for navigating Ruby through the digital game world by clicking in the game world. The players' perspective of the game world is through Ruby's eyes. This means that each player moves to the same place in the game world as where the driver navigates to. Each of the mini-games requires the players at some point to provide Ruby with a group answer. The decider is responsible for communicating this answer to Ruby. Finally, the remaining players are assigned the collector role. These players are responsible for collecting graffiti tags while navigating through the city. Once enough graffiti tags are collected, the graffiti mini-game is started. The player roles remain the same throughout the game.

Ruby's mission enables us to focus on children's verbal social communication because it stimulates team work through verbal communication. Furthermore, the game does not include any game-specific communicative tools such as pinging or emotes, which eliminates the influence of nonverbal communication.

3.3 Measures

Socioemotional Skills. A baseline measure of socioemotional skills was established through the Emotional Awareness Questionnaire (EAQ) [45]. The EAQ consists of six sub-scales that are related to the various constructs that are socioemotional skills: (1) differentiating emotions (2) verbal sharing of emotions, (3) not hiding emotions, (4) bodily awareness of emotions, (5) attending to others' emotions, and (6) analyses of (own) emotions. Although the EAQ does not provide any norm scores, we assumed that the EAQ is suitable for our needs, particularly as it is used as a baseline comparison between participants. The EAQ has been previously validated in various populations [1, 30]. Internal consistency of the EAQ has been validated within our sample. A Cronbach's Alpha of 0.77 was found.

Personality. Personality was measured through the composite score of the Big Five Questionnaire (BFQ), where higher scores are indicative for more resilient and adaptive personality traits [6, 46]. These personality traits may affect observable social interactions, as the BFQ has previously been associated with higher social competencies, social support from peers, and relationship success [39, 54, 60, 63, 64]. The BFQ measures personality on five sub-scales: (1) openness, (2) conscientiousness, (3) extraversion, (4) agreeableness, and (5) emotional instability. Emotional instability was reverse coded to compute the total score to indicate resilient and adaptive personality traits.

A shortened, Dutch version of the BFQ for children was used for this study. A Dutch version of the full BFQ for children has been previously constructed and validated by Muris et al. [40]. Because our study involved children and required administering multiple instruments, we opted to use a shortened version of the BFQ for Children (BFQ-CS) to avoid overburdening the participants. Although, shortened versions of the BFQ for children have been validated in various languages across different countries [11, 37, 38, 47], a validated Dutch version of the

BFQ-CS is currently unavailable. Therefore, we constructed our own version of the BFQ-CS based on Bore et al.'s 2020 English version, which has been validated in an Australian sample. Questions from the Dutch BFQ-C ([40]) were selected based on the questions listed in [11]. For most questions a (near) one-to-one translation could be identified in Muris et al. [40]. The remaining items were selected to align with the same personality dimension and to match the content of the English items as closely as possible, ensuring they were the best fit from the Dutch BFQ for children. The total Big Five scores were computed from the questionnaires and included in our analyses.

Internal consistency using Cronbach's Alpha was computed for the Dutch BFQ-CS version in our sample. A Cronbach's Alpha of 0.81 was found which is sufficient for analysis at a group level [41].

Social Familiarity. Ruby's Mission requires players to share their emotions what can be perceived as an intimate topic. The game was designed to be played with close peers (i.e., friends, family, or classmates), such that the players would feel comfortable sharing their emotions. We measured social familiarity, to establish how familiar the participants in a group are. Each participant in a group would answer the following two questions for every other participant in the group (translated from Dutch): (1) "How often per week do you meet up with this classmate?" and (2) "How well do you know this person?". Both questions were answered on a five-point Likert scale. The possible answers for the first question were "never, rarely, sometimes, often, very often". The possibilities for the second question were "not well, a little, well, very well, extremely well".

After data collection, we decided to remove the first question on social familiarity. First, the question did not specify *how* the children meet after school. Some may interpret the question as in-person, while others may consider online as well. Secondly, the answers to this questions were generally quite low. A quick plot revealed that the results were right-skewed. As a result we included only the scores for the second question on social familiarity in the analyses.

We consciously avoided asking the participating children to rate how good of a friend they considered the others. This was due to the possibility that their responses could be seen by others, despite our instructions to keep their answers private. If two children gave differing responses regarding their friendship, it might have led to discomfort or confusion. This was a risk we aimed to minimize.

3.4 Procedure

The experiments took place at the participating elementary schools. Each school reserved a separate classroom that was used for the experiments. Other students were instructed to not enter this room for the duration of the day. In this room four laptops would be placed at four different tables used for playing Ruby's Mission. The tables were setup in a two-by-two configuration. The seating arrangement placed two participants side-by-side, with pairs facing each other (see Figure 2).

At the start of the day, the researcher provided a brief plenary introduction on the purpose of the research. The students for whom informed consent was signed, were reminded that they only had to participate if they wanted to themselves. If they did not want to participate, they were allowed to withdraw (either by telling the researcher or their teacher). It was also mentioned that they were allowed to stop the experiment at any point without specifying a reason.

After the brief introduction, all participants were handed the EAQ and BFQ-CS questionnaires. These were filled in by each participant simultaneously. All participants were also handed five stickers with a unique code on them. These codes were used to identify their questionnaires, and as login-code for playing Ruby's Mission. They were instructed to hold on to their questionnaires and stickers until it was their turn to play the game.

The teacher was asked to make groups of three or four students that would play the game together. They were instructed to have some variety within the group (e.g., to not only create groups consisting of good friends, or

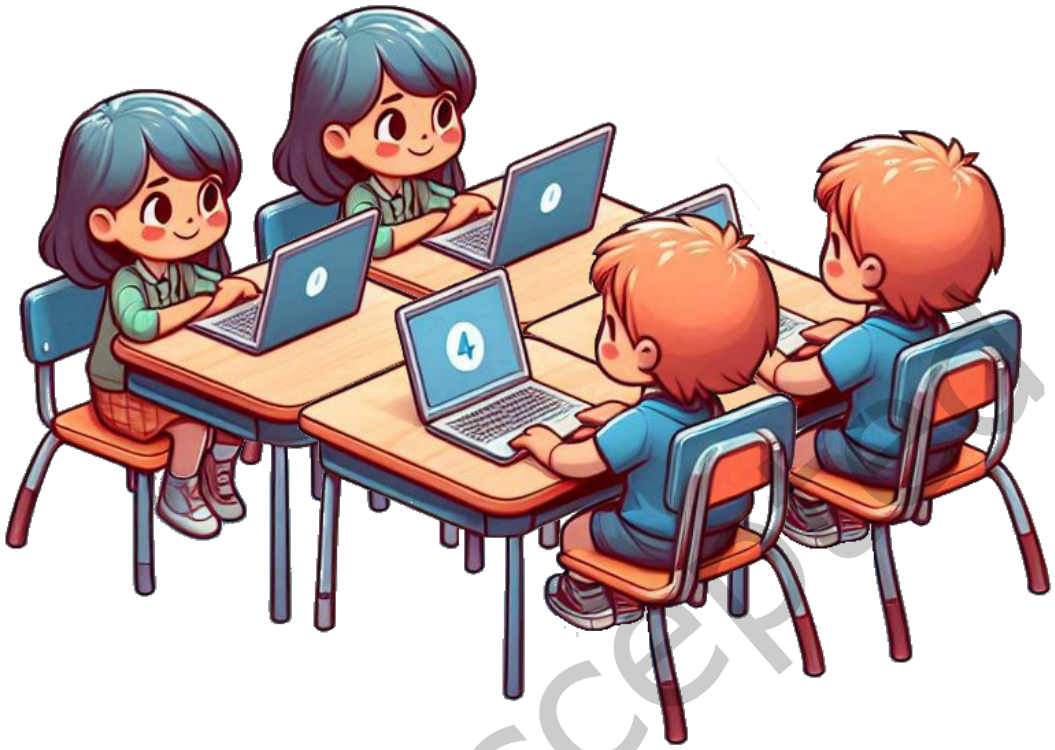

Fig. 2. Overview of the participant's seating arrangement while playing the experiments. When played in groups of three, one seat remains empty. Generated with Google's Gemini AI. Edited for this paper.

create groups pairing only high-scoring students with high-scoring students, and vice-versa). In this way, we would guarantee a degree of variety between groups.

Next, the groups would play Ruby's Mission. The experiments lasted approximately 30 minutes per group. Each experiment would start with a brief introduction on how the video game was being played (although there was also an introduction in the game, teaching the children how to play). Then, the children were instructed to put on their headsets and to not remove them while playing, as that was important for the recordings. They were also instructed to not move from their devices, to best simulate a digital online setting. Finally, it was made clear that the researcher did not participate in the game in any way. They were only there in case the participants would get stuck in the game or had any other important questions. After logging into the game, the game would be started by the player who created the lobby.

After finishing playing Ruby's Mission, the group was asked to fill out the questionnaire on social familiarity as described in Section 3.3. They placed a sticker with their own player code on the other participants' questionnaires. Then they could fill out the questions for the corresponding participant. Finally, the participants would hand over all their questionnaires (EAQ, BFQ-CS, and social familiarity) to the researcher and fetch the next group.

Once all groups finished playing Ruby's Mission, the researcher would do a plenary conclusion of the experiments, where the students were able to ask any questions they had to the researcher.

3.5 Annotation of Verbal Interaction

Recordings of the play sessions were annotated on social interactions based on the stimulus-response (SR-) model for the analyses. Each participant played the video game from a laptop, using a headset and a mouse, provided by Utrecht University. While playing, the participants were recorded via the webcam of their laptops and through the microphone of their headsets, resulting in one recording per participant.

As described previously, the SR-model characterizes social interaction as the way in which persons mutually influence one another [5, 19, 50]. It describes how every social action may be determined by the social action of another person [5]. Our set of annotation rules have been build upon this definition of social interactions.

Our annotations for social interaction considered only verbal actions. A **verbal action** was considered any sound an individual produces using their voice and that contains language. A new verbal action was annotated either when the participant clearly switched the topic of what they were saying, or when the type of verbal action changed.

According to the annotation rules, a verbal action could either be annotated as a 'stimulus', 'response', or left unannotated (see Section 3.5). A **stimulus** is either (1) a verbal action that is intended for others to respond to verbally (through another verbal action), or in-game (through an action in the video game); or (2) a verbal action that others respond to through a *verbal action*, even though this was not the speakers intention. Stimuli were categorized into five sub-categories:

(1) **Question:** a verbal action that contains a question directed to at least one *other* person in the group. For example, *"Did you really break your mothers phone?"*
(2) **Command:** a verbal action that contains a command directed to at least one *other* person in the group. For example, *"Go to the left!."*
(3) **Remark about another person:** a verbal action that contains a remark *about* at least one *other* person in the group. For example, *"[She] is such a bad driver."*
(4) **Remark to another person:** a verbal action that contains a remark meant for at least one *other* person in the group. Verbal actions about the shared task (i.e. the game) were also considered as this sub-category. For example, *"The blue one! I am going to the blue one!"*
(5) **Unintentional:** any verbal action that *another* person in the group responds to, even though this may not have been the speakers intention. For example, *'child A'* reads aloud the text displayed on the screen as they are waiting for the other players to finish writing their answer. A verbal action consisting of reading text on the screen aloud would typically not be categorized as a stimulus. However, *'child B'* reacts *"'I am a really slow at typing, so ...'*, apologizing for typing slowly, making the others wait. Therefore, the verbal action of *'child A'* is annotated as a stimulus and the verbal action of *'child B'* is annotated as a response.

A **response** is any verbal action that is a reaction to *another* player's *verbal action* (not an in-game or physical action). In case a verbal action could both be considered a stimulus and a response, it was always annotated as a response. No further sub-categories were distinguished for responses.

Annotation Rules. A set of rules was constructed to determine how to categorize verbal actions:

(1) A verbal action is a stimulus when it fits within any of the sub-categories listed previously for stimuli.
(2) A verbal action is considered a response when this action is a reaction to another person's verbal action, regardless of whether this action was a stimulus or a response.
(3) A stimulus can be used as a response to another person. In this case, the verbal action is *always* annotated as a response.
(4) When a person follows up with multiple consecutive answers within the context of a response to another person, each of these actions are categorized as a response.

(5) During a conversation (i.e., a stimulus followed by at least a single response) the topic of the conversation may transition smoothly. In this case, consecutive verbal actions are continued to be categorized as responses. When a verbal action introduces an abrupt change of topic, the action is not categorized as a response.
(6) When it is unclear whether a verbal action categorizes as a response and the verbal action clearly categorizes as a stimulus, the verbal action is then annotated as a stimulus.
(7) When it is not evident if a verbal action categorizes as a stimulus or as a response, the verbal action is not annotated.
(8) When it is evident that a verbal action does not categorize as a stimulus or as a response, the verbal action is not annotated.
(9) Verbal actions where the language used is inaudible, making it impossible to determine whether it constitutes a stimulus or a response, are not annotated.
(10) Any verbal action, either stimulus or response, that is directed at any other person than the fellow players is not annotated.

Figure 3 displays a rather simplified version of a decision tree on how to annotate a verbal action based on the previously described rules. In the figure, rules 9 and 10 are assumed for the verbal action that is to be annotated, meaning that the audibility does not obstruct annotation (rule 9), and that the verbal action was directed at a fellow player (rule 10). Rule 4 is not captured within the figure as it is in effect at a higher level (i.e., within the context of multiple verbal actions).

Speech Measures. Four different variables were then extracted from the annotations of social interaction for each participant:

(1) *Proportion of speech:* this was computed as the sum of the duration of all verbal action that were annotated as a social interaction (either a stimulus or response), divided by the total duration of the game's section being investigated in seconds.
(2) *Frequency of social interactions:* this was computed as the total number of verbal actions that were annotated as a social interaction, normalized by the duration of the section being investigated in seconds.
(3) *Responses:* this variable was computed as the total number of verbal actions that were annotated as a response for a participant, divided by the total number social interactions for this participant.
(4) *Overlap:* was computed as the total number of occurrences where the participant started a social interaction while any of the other participants where currently speaking (i.e., performing a social interaction). This value was normalized by dividing the number of occurrences of overlap by duration of the section in seconds. As we were investigating groups consisting of more than two persons, a person may start their social interaction while multiple other speakers are already speaking. Therefore, a single social action may result in multiple overlapping occurrences, possibly resulting in larger values for the proportion of overlapping interactions than for the frequency of social interactions.
When it is clear that one person's turn is coming to an end, another person may take over the turn while the initial speaker is finishing their sentence [53]. To account for the possible overlap between one person finishing their social interaction while the other starts their social interaction, overlap was only considered when the participant who was already speaking would continue to do so for at least 100 ms.

Each measure of social interaction was extracted for duration of three sections of the game session: (1) the entire game session, (2) the mini-games, and (3) the cooperative sections of the mini-games. A social interaction was considered part of one of these three phases when the start of the interaction occurred during this section of the game. If an interaction had start before, but continued during the specific game section, it was not considered part of the section.

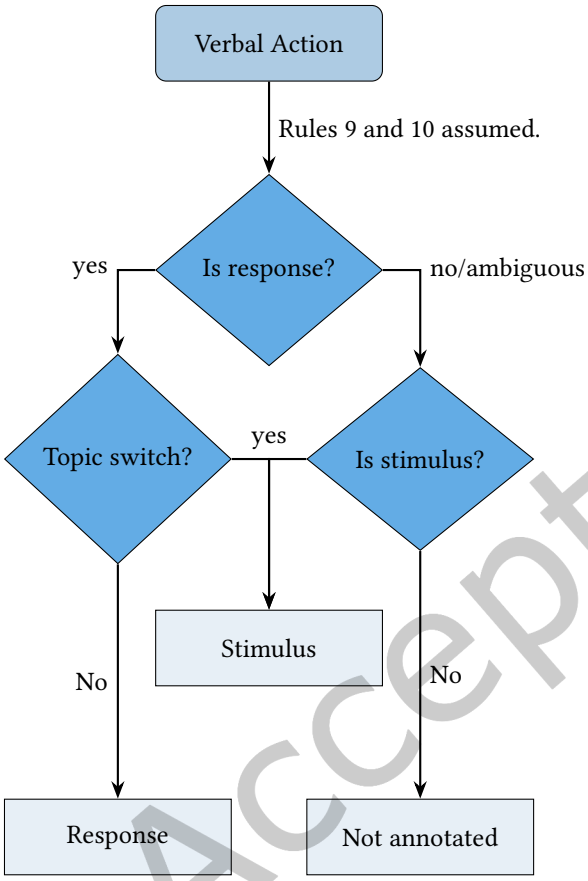

Fig. 3. Simplified decision tree of the annotation rules described in Section 3.5. In this decision tree, it is assumed that the verbal action's audibility is not obstructing annotation (rule 9), and the verbal action is directed at a fellow player (rule 10). Furthermore, rule 4 is not captured in the decision tree as this rule is in effect at a higher level (i.e., within the context of multiple verbal actions).

Annotation Process. A custom annotation tool was developed for the annotations of the recordings in the programming language C/C++ for the Windows operating system by the author DA. The main purpose of the tool was to be able to play back multiple recordings simultaneously, while maintaining separate audio channels for each media file. Another requirement was to be able to add annotations for specific media streams (i.e., participants), and to add multiple types of annotations (for example, SR-labels, or game-event timestamps). Furthermore, as there was some delay up to several seconds between the start of the recordings for the participants due delays from the networking and possibly other hardware components, the tool also required the option to synchronize the streams manualy. Although the tool has not been published, it may be made open source and open to the public in the future.

Two students, both studying psychology at the psychology department of Utrecht University, were recruited as research assistants to assist in the annotation of the data. As a first step, inter-rater reliability was calculated between the three raters using Fleiss' Kappa until substantial agreement was achieved consistently. Note that

	Participants	Boys	Groups	4p. groups	Age (mean)	EAQ (mean)	Familiarity (mean)	Big-5 (mean)
School A	55	27	15	10	10.98	2.19	2.43	2.63
School B	31	15	8	7	10.94	2.15	2.69	2.56
School C	15	9	4	3	8.93	2.05	3.10	2.44
Total	101	51	27	20	10.66	2.16	2.61	2.58

Table 1. Descriptive statistics of the participants. Groups refer to the grouping of participants for playing Ruby's Mission. 4p. groups indicates how many groups consisted of four participants. The remaining groups consisted of 3 participants. Familiarity refers to the social familiarity scores.

inter-rater reliability was solely computed for the labels that were assigned to predetermined verbal actions in a video recording, and not for annotating verbal actions. It was assumed that the raters were able to determine consistently whether a participant produced a verbal action (i.e., a sound with their voice containing language). After multiple iterations of testing and reviewing the annotation rules, consistent reliability was achieved. The last three iterations achieved Kappa values of 0.637, 0.639, 0.608, respectively, indicating substantial agreement between raters.

3.6 Statistical Analysis

Data preparation and analyses were conducted using R version 4.4.0. For two participants, the familiarity with group members score was missing, and these values were therefore imputed using the mean.

A statistical analysis was performed for each of the social interaction measures described in Section 3.5. These analyses were repeated for the social interactions over the entire game session, for the mini-game sections, and for the cooperative parts of the mini-game sections, resulting in a total of twelve analyses.

To account for the hierarchical data structure, where individual observations were nested within groups and groups within schools, multilevel analyses were performed using the nlme package [43]. For each of the twelve study outcomes, we defined a full model that included players' sex, player role, social familiarity, EAQ-score, BFQ-score (reflecting adaptive personality), and group size as fixed predictors (level 1). A random intercept for groups nested within schools was included as a level 2 random effect to account for systematic differences between groups and schools.

Following the specification of the full model, a stepwise backward selection process was employed to improve model parsimony. At each step, the fixed predictor with the highest p-value was removed, resulting in six multilevel models for each outcome (the full model and five reduced models). The performance package was then used to visually compare eight different model indices [36]. The model with the best overall performance across these indices was interpreted in relation to our hypotheses. Finally, the effect size was computed for each of the statistically significant results. A beta-value of 0.10 to 0.29 indicates a small effect size, a value between 0.30 to 0.49 indicates a medium effect size, and a value of 0.50 or greater indicates a great effect size [16].

4 Results

4.1 Sample

A total of 108 children from three different Dutch elementary schools participated in our study. One of the school offered a specialized educational track for gifted children (school indicated with 'C' in Tables 1 and 2). While individual IQ scores were not collected or compared across the participants, schools A and B represent mainstream elementary education, whereas school C's population is officially designated as high-performing by the institution. The participants played Ruby's Mission in groups of three or four players, for a total of 29 groups.

	Total game				Mini-games				Cooperative sections			
	Speech (%)	Inter.	Resp. (%)	Overlap	Speech (%)	Inter.	Resp. (%)	Overlap	Speech (%)	Inter.	Resp. (%)	Overlap
School A	16.26	0.10	55.21	0.10	15.10	.094	67.94	0.11	16.01	.097	69.47	0.11
School B	18.11	0.12	53.71	0.11	16.49	0.10	65.65	0.11	17.77	0.11	67.69	0.12
School C	16.79	0.11	53.55	0.08	15.29	.093	65.46	.081	22.28	0.14	65.19	0.12
Boys	18.06	0.12	52.08	0.11	16.38	0.10	64.81	0.11	18.10	0.11	67.46	0.12
Girls	15.68	0.10	57.07	0.10	14.67	.093	69.05	0.10	15.88	0.10	69.17	0.11
Driver	17.38	0.11	61.44	0.10	16.19	0.10	68.22	0.10	18.17	0.11	68.95	0.11
Decider	17.94	0.12	50.41	0.10	16.46	0.10	64.05	0.11	18.14	0.11	64.65	0.12
Collector	16.01	0.10	52.68	0.10	14.64	0.09	67.70	0.10	16.68	0.10	70.03	0.12
3 players	16.70	0.11	50.33	0.07	15.24	0.09	62.95	0.08	15.05	0.09	65.35	0.08
4 players	16.96	0.11	55.60	0.11	15.64	0.10	67.90	0.11	18.12	0.11	69.06	0.13
Total	16.91	0.11	54.50	0.10	15.55	0.10	66.87	0.11	17.48	0.11	68.29	0.12

Table 2. Data for the proportion of speech (Speech), frequency of social interactions (Inter.), responses (Resp.), and overlap per game-section that was investigated. The table indicates the average values for the sample indicated in the left-most column. The letters 'A', 'B', and 'C' in this column indicate the different schools (matching Table 1). '3 players' and '4 players' refer to groups consisting of 3 and 4 players, respectively.

Two groups were deleted because the quality of the recordings were not good enough to accurately annotate social interactions. After removal of these groups, data for 101 participants remained divided over 27 groups. 20 out of 27 total groups consisted of four players, the remaining 7 groups consisted of three players. Out of the 101 participants, 51 participants were boys. On average, the participants were 10.66 years of age. Please refer to Table 1 for a descriptive overview of our sample.

Table 2 provides an overview of the descriptives of the social interactions grouped by school, sex, and all participants. The results are displayed for each of the game sections that were investigated. Results show similar interactions across the different schools for the various sections of the game. The most noteworthy descriptive difference being the larger proportion of speech for the children from the gifted program (school 'C') during the cooperative sections of the game. Similarly, no large differences were found between boys and girls. Table 2 does reveal that boys, on average, may have performed more social interactions than girls, while girls have slightly higher responses than boys. Finally, a visible trend among all participants was that the proportion of responses increased when playing the mini-games (both over the entire mini-game as for the cooperative sections) as compared to the total game. No large differences are visible between the entire mini-games and the cooperative sections.

4.1.1 Analyses for the Total Game. This subsection discusses the results for the analyses of the social interaction for the entire game session. Supplementary Figure 4 shows the comparison of model performance indices for each outcome. An overview of the results can be found in Table 3.

No significant predictors were found for the proportion of speech or the frequency of social interactions, indicating that none of the variables had a notable impact on how much each participant spoke during the game session.

Player roles were found to be a significant predictor for the proportion of responses. Specifically, participants that were assigned the Driver role had a higher proportion of responses compared to those in the Collector ($p = 0.03$, $\beta = 0.75$) and Decider ($p = 0.01$, $\beta = -0.82$) roles. No significant difference was found between the Collector and Decider ($p = 0.629$).

	Speech			Interactions			Responses			Overlap		
	b	t	p	b	t	p	b	t	p	b	t	p
Intercept	3.87	0.61	.547	0.08	5.50	< .001	45.36	3.32	.001	-0.09	-1.13	.263
Sex[a]							3.57	1.65	.103			
Player role												
Decider (vs. Collector)							-1.28	-0.49	.629			
Decider (vs. Driver)							-9.43	-3.17	.001			
Driver (vs. Collector)							8.15	3.11	.003			
Group size							5.29	2.00	.057	0.04	2.09	.047
Social familiarity	1.51	1.53	.130	0.01		.053				0.01	1.80	.076
Socioemotional skills	4.21	1.49	.141									
Personality							-5.65	-1.71	.092			

Table 3. Results of the final multi-level models for the entire play session of Ruby's Mission. Player roles and group size were found to be significant predictors of the proportion of responses. Group size also was a significant predictor for the overlapping social interactions. No significant predictors were identified for the proportion of speech or for the frequency of social interaction.

In the analysis of overlapping social interactions, group size emerged as a significant predictor ($p = 0.047$, $\beta = 0.30$), with larger group sizes leading to a higher proportion of overlapping interactions. This indicates that participants in larger group sizes were more likely to interrupt others' social interactions.

In addition to the significant findings, we also observed trends that approached significance, even though they did not meet the significance threshold. Nevertheless, these trends are worth mentioning as they might reveal interesting trends. Social familiarity was borderline significant ($p = .053$, $\beta = 0.20$) for the frequency of social interactions, where participants who were more familiar with their group members, tended to interact more frequently. Additionally, group size was borderline significant ($p = 0.057$, $\beta = 0.18$) for the proportion of responses. Larger group sizes were related with higher proportions of responses, implying a trend that participants in larger groups were more likely to spend a greater portion of their social interactions in conversation with others. Finally, social familiarity was also borderline significant ($p = 0.076$, $\beta = 0.14$) for the proportion of overlapping interactions, implying a trend where participants who were more familiar with their group members tended to have more overlapping interactions.

4.1.2 Analyses for the Mini-Games. This subsection discusses the results for the analyses of the social interaction during the mini-game sections of the game session. Supplementary Figure 4 shows the comparison of model performance indices for each outcome. An overview of the results can be found in Table 4.

No significant predictors were found for the proportion of speech or the frequency of social interactions during the mini-game sections of Ruby's Mission, suggesting that neither had a considerable effect on how much each participant spoke during the game session.

The BFQ-score was found to be a significant ($p = 0.022$, $\beta = -0.22$) predictor of the proportion of responses during the mini-games. More adaptive and resilient personalities were associated with a lower proportion of responses. Additionally, social familiarity was also found to be a significant ($p = 0.026$, $\beta = 0.14$) predictor for the proportion of responses. Higher familiarity would lead to a lower proportion of responses.

Both socioemotional skills scores ($p = 0.004$, $\beta = 0.19$) and group sizes ($p = 0.028$, $\beta = 0.34$) were found to be significant predictors of the proportion of overlapping interactions. Higher socioemotional skills-scores were associated with greater proportions of overlapping interactions, suggesting that children with better socioemotional skills were more likely to start a social interaction while another person was already performing a social interaction. Larger group sizes were also associated with a higher proportion of overlapping interactions,

	Speech			Interactions			Responses			Overlap		
	b	t	p	b	t	p	b	t	p	b	t	p
Intercept	1.88	0.33	.740	0.03		.337	80.73	5.44	< .001	-0.11	-1.66	.101
Sex[a]												
Player role												
Decider (vs. Collector)												
Decider (vs. Driver)												
Driver (vs. Collector)												
Group size							4.13	1.45	.161	0.04	2.34	.028
Social familiarity	1.19	1.36	.177	0.01	1.57	.122	-3.37	-2.27	.026			
Socioemotional skills	4.89	1.96	.054							0.03	2.94	.004
Personality				0.02	1.76	.083	-8.03	-2.34	.022			

Table 4. Results of the final multi-level models for the mini-game sections of Ruby's Mission. Personality was found to be significantly predictive of the proportion of responses and of the proportion of overlapping social interactions. Group size was also found to be a significant predictor of the proportion of overlapping social interactions.

	Speech			Interactions			Responses			Overlap		
	b	t	p	b	t	p	b	t	p	b	t	p
Intercept	0.12	0.02	.987	0.05	2.87	.005	95.99	9.11	< .001	-0.17	-1.90	.062
Sex[a]												
Player role												
Decider (vs. Collector)												
Decider (vs. Driver)												
Driver (vs. Collector)												
Group size										0.05	2.41	.024
Social familiarity	3.02	2.52	.014	0.02	3.19	.002	-3.09	-1.75	.085	0.01	2.07	.042
Socioemotional skills	4.34	1.35	.182							0.03	1.94	.056
Personality							-7.64	-2.01	.048			

Table 5. Results of the final multi-level models for the cooperative sections of the mini-games. Social familiarity was found to be a significant predictor for the proportion of speech, for the number of social interactions, and for the proportion of overlapping interactions. Personality scores were found to be predictive of the proportion of responses. Finally, group size was significantly predictive of the proportion of overlapping interactions.

indicating that participants in larger groups were more likely to start a social interaction while another person was already performing a social interaction.

Beyond the significant results we also identified trends that approached statistical significance, potentially pointing out meaningful relationships. Socioemotional skills scores were borderline significant ($p = 0.054$, $\beta = 0.19$) for the proportion of speech, suggesting a trend where higher socioemotional skills scores were associated with larger proportion of speech in social interaction. Personality score was borderline significant ($p = 0.083$, $\beta = 0.17$) predictor of the frequency of social interactions. More adaptive and resilient personality was associated with a higher number of social interactions.

4.1.3 Analyses for the Cooperative Sections of Mini-Games. This subsection discusses the results for the analyses of the social interaction during the cooperative parts of the mini-game sections. Supplementary Figure 4 shows the comparison of model performance indices for each outcome. An overview of the results can be found in Table 5.

Social familiarity was found to be a significant predictor of the proportion of speech in social interaction ($p = 0.014$, $\beta = 0.24$), and of the frequency of social interactions ($p = 0.002$, $\beta = 0.30$). Participants who felt more familiar with their group members showed larger proportions of speech in social interactions, and had more social interactions. The results indicate that these participants more actively engaged in social interaction.

Personality score was a significant ($p = 0.048$, $\beta = -0.19$) predictor of the proportion of responses, where more adaptive and resilient personality types were associated with lower proportions of responses.

Group size was a significant ($p = 0.024$, $\beta = 0.36$) predictor for the proportion of overlapping interactions. Larger group sizes were associated with larger proportions of overlapping interactions. Additionally, social familiarity was also a significant ($p = 0.042$, $\beta = 0.14$) predictor for the proportion of overlapping interactions, where participants who felt more familiar with their group members were associated with higher proportions of overlapping interactions.

Although some results did not quite reach statistical significance, they may be indicative of interesting trends as they approached significance. Social familiarity was borderline significant ($p = 0.085$, $\beta = -0.18$) for the proportion of responses, revealing a trend where participants who indicated to feel more familiar with the others had lower proportions of responses. Additionally, socioemotional skills score was borderline significant ($p = 0.056$, $\beta = 0.03$) for the proportion of overlapping interactions, suggesting that participants with better socioemotional skills engage in more overlapping interactions.

5 Discussion

The present study set out to explore how children's socioemotional skills relate to their real-time social interactive behaviour, specifically verbal communication, within an online multiplayer video game context. For this purpose we recorded and annotated the game sessions of an applied multiplayer video game, utilizing audio recordings to investigate real-time social interaction between players. Children's social interactions were then categorized following a SR-model [5, 19, 50]. Social interactions were then operationalized for a participant through four measures: (1) the proportion of speech in social interaction as compared to the game section; (2) the number of distinct social interactions; (3) the proportion of social interactions that were considered a response; and (4) the proportion of social interactions that were overlapping another player's ongoing social interaction. The relation between socioemotional skills and social interactions were analyzed through a multilevel analysis, including several other measures as discussed in Section 3.3.

5.1 Socioemotional Skills

Our primary aim was to investigate how socioemotional skills affect real-time verbal communication patterns. Better socioemotional skills were predictive of more overlapping interactions over the entire mini-game sections. No relation was found between socioemotional skills and any of the other measures in this study.

In the present study, overlapping interaction was defined as a person starting a social interaction while another person was performing a social interaction. As described in Section 3.5, overlap within social interaction is typically considered erroneous from the turn-taking perspective. One would expect that a person with better socioemotional skills would less frequently make these overlapping turn-mistakes. Although falling just short of statistical significance, a similar trend was found for the cooperative sections of the mini-games.

An explanation for these results may be that children with better socioemotional skills are more eager to respond to, or to share their thoughts with their peers. This may be reflected by the trend that children with higher socioemotional skills had on average higher proportions of speech.

A second explanation could be that participants with better socioemotional skills would more frequently interrupt other players to restore the conversations when these would become too disorganized. We observed that the discussions during the mini-games would at times become quite chaotic or the topic would drift from

the task at-hand. We would then observe that some participants would call the others back to the task at hand (i.e., solving the mini-game), which would interrupt any ongoing conversation.

Another observation is that when one person would make a remark that initiated a conversation, typically multiple people would respond. Within turn-taking, there are several mechanics to hand-over the turn to another person. One of these, which was observed often, is that a person leaves a silence such that another person may take the turn [50]. In these situations it was often unclear who would take the next turn, resulting in multiple participants speaking concurrently. This pattern would continue throughout the discussions in the mini-games.

5.2 Personality

Personality was predictive of a participant's proportion of responses for the entire mini-games and for the cooperative sections of the mini-games, where more adaptive and resilient personality types predicted lower proportions of social interactions. Initially, we expected that children with these personality traits would in general have higher proportions of responses. Big-5 was previously associated with higher social competencies, better social support, and more relationship success [39, 54, 60, 63, 64]. Therefore we expected that these children would have better social skills, and consequently engage more in conversation with their peers.

In this study, proportion of responses was defined as the proportion of a participant's responses relative to their own total interactions. One limitation of this measure is that it lacks context within the group; it does not account for the interactions levels of others in the group. Consequently, this definition may not full reflect a participant's relative level of engagement in conversation compared to the others. For example, children with higher BFQ scores may have fewer responses relative to others, despite being more actively engaged in conversation compared to their group members.

Another possible explanation for this unexpected finding is the observed trend where more adaptive and resilient personality traits were positively associated with a higher frequency of social interactions. Participants with higher BFQ scores may have been more likely to initiate conversation within the group, or to communicate in-game information, leading to an overall increase in their interaction frequency. This increase in social interactions could lower their proportion of responses relative to their total interactions. Therefore, these results might reflect these children's tendency to actively express themselves during the game, focusing more on initiating interactions rather than only responding to the other players.

5.3 Group size and Social Familiarity

Not surprisingly, group size was found to be a clear predictor for overlap in speech during each section of the game. When moving from a three-person group to a four-person group, the number of possible relational pairs (dyads) doubles from three to six. Consequently, the mathematical probability of overlapping communication increases substantially. This is reflected in our data, which reveals increases of 60.46%, 48.38%, and 66.43% in overlapping interactions for the entire game, mini-games, and cooperative sections, respectively, when playing in groups of four as compared to groups of three. Within conversation with multiple people, especially within a game setting, it becomes more difficult to regulate turn-taking, most likely resulting in natural overlaps. Although we can not yet draw any conclusions on what kind of effect this will have for the learning objectives or for the game experience, applied game designers should be aware of the potential effects that group sizes may introduce.

Not surprisingly, group size was found to be a clear predictor for overlap in speech during each section of the game. As Ruby's Mission was played in groups of three or four children, we may have expected an increase of approximately 33% in overlapping interactions when playing in groups of four as compared to groups of three. However, the data reveals larger increases of 60.46%, 48.38%, and 66.43%, respectively, for the entire game, mini-games, and cooperative sections. Within conversation with multiple persons, especially within a game setting, it may be quite difficult to determine who will respond to the previous social action. It can be seen that as

group sizes increase it becomes more difficult to determine who can talk next. Although we can not yet draw any conclusions on what kind of effect this will have for the learning objectives or for the game experience, applied game designers should be aware of the potential effects that group sizes may introduce.

Interestingly, social familiarity also emerged as one of the more important predictors for social interaction. It was found to be a significant predictor for each of the measures for social interactions across the mini-game and cooperative phases of Ruby's Mission. It shows that it affects several aspects of social interactions across various game-contexts. We assumed that there would be a high baseline level of social familiarity between the participants, as most have been classmates for multiple years. But, we found considerable differentiation in social familiarity and it appeared to be a strong predictor of social interactions, highlighting the importance of the social context within which the conversation takes place.

5.4 Task Type and Player Role

Interestingly, different predictors for social interactions were identified for the two different types of tasks in Ruby's Mission (i.e., navigation and collection phase, and the mini-game phases). The tasks during the driving phase are less structured, even though there is a clear goal: navigating to the next mini-game and collecting graffiti tags. Which path the players take, which mini-game they choose next, and whether they focus on finding the next mini-game or collecting graffiti texts is quite open. In this phase, external variables such as player role, group size, and social familiarity appeared to be predictive of social interactions.

The mini-games on the other hand, are more structured. In this phase, the players are clearly instructed to provide an answer to a specific question on screen. It specifically asks the players to cooperate and discuss their answers. We found that internal factors such as socioemotional skills, personality, and social familiarity were predictive of social interactions. These results highlight the importance of the context (in this case type of task) on how social interactions are affected differently.

Player role was found as a significant predictor for the proportion of responses over the entire game session. Specifically, the driver role was associated with greater proportions of responses, whereas no significant difference was found between the collector and decider roles (see Table 3). Consistent with our pilot study [3], we observed that the driver was frequently verbally instructed by co-players on where to navigate.

From a game design perspective, Ruby's Mission utilizes asymmetrical player roles to create a player interdependence, stimulating verbal communication and inclusion. During the navigation phase, the driver's primary task is to move the avatar (Ruby) through the 3D world toward the next mini-game. Because all players, including the driver, have access to a mini-map displaying the locations of available mini-games, the driver possesses all the necessary information to complete their task independently. Consequently, while the other players might suggest which mini-game to play next, the driver is not mechanically required to initiate communication to fulfill their specific task.

Conversely, the other roles are tightly dependent on the driver's actions. Their responsibility during the navigation phase is to collect graffiti tags scattered throughout the environment. Because all players share a single visual view tied to the driver-controlled avatar, the other players must explicitly instruct the driver on where to move when they spot a tag. This asymmetrical control naturally forces a specific communication loop: the observing players issue commands (stimuli), and the driver reacts (responses). When designing applied games, it is important to consider how specific type of player role dependencies affect resulting interactions. To create a more balanced distribution of communication types, the dependency between the driver and the other roles could be adjusted. For example, removing the driver's access to the mini-map would require them to actively ask the other players for directions. While this could successfully prompt the driver to initiate interactions, it is important to note that asking questions remains a qualitatively different type of communication than issuing

commands. This highlights how specific game mechanics mechanics relate to player's verbal communication patterns.

Beyond the player role dependencies established by the game's mechanics, the observed communication differences between the driver and the other players could be explained by an uneven distribution of cognitive load. Navigating Ruby through the 3D world appeared to be a highly demanding task, whereas the mechanics of the other roles were comparatively less taxing. Furthermore, because the participants were playing the game for the first time, they were required to simultaneously master the mechanics and execute their specific role responsibilities. Consequently, we assume that the driver's working memory was heavily taxed by both the active demands of navigation and the continuous instructions from other players, leaving bandwidth available to initiate verbal communication.

5.5 Sex, and School

Sex was not a significant predictor for any of the social interaction variables for any of the gameplay phases.

Initially we expected to find at least a small effect on social interaction based on the school that a participant came from. Although we did not collect any proper data on programmes, or efforts spent on improving socioemotional skills, the main researcher did discuss this with the participants' teachers. Each teacher indicated to spend some effort on their students' socioemotional skills, varying from a daily check-in to following full socioemotional skill training programmes. Moreover, the school indicated with 'C' in Tables 1 and 2, exclusively enrolled students classified as gifted. While we did not collect quantitative intelligence measures to establish baseline cognitive differences between the schools, the teacher at school C indicated that their students may face more social difficulties than their peers. Nevertheless, no significant differences on any of the social interaction measures was found between the different schools.

6 Limitations and Future Works

As a first explorative study on the relation between socioemotional skills and social interactions in children playing a cooperative video game, we used relatively simple measures of social interaction that related specifically to the individual; i.e., the frequency of a participant's basic interactions normalized over time. Although interesting results were found in this study, we believe that it is important for future studies to increase the complexity of social interaction measures that may reveal more about the group dynamics at play. For example, one may include measures for an individual that are relative to the group, include the direction of interactions, or include more fine-grained interactions (e.g., distinguish different types of responses). Including these type of measures places the individual's performance within the context of the group, providing insights in the social group dynamics.

Although some relations were found between socioemotional skills and social interactions, other variables were more often predictive of social interaction. In the present study, we focused solely on quantitative measures for social interactions. It may be that socioemotional skills rather affect the contents and meanings of the interactions. Therefore, we propose that future studies not only focus on quantitative measures of social interaction, but also on qualitative measures, such as identifying the dominant purpose of the communication (e.g., giving instructions versus making peer evaluations) in relation to the specific game situation.

Furthermore, it would be interesting to investigate how communication patterns shift across different game genres and competitive frameworks. Comparing social interactions in open-world sandbox games where players cooperatively build towards shared goals, against high-stakes competitive environments could highlight the impact of game mechanics on social behavior. Exploring these distinct environments would also enable deeper investigations into dynamic player types, specifically how a player's motivation, effort, and communication style adapt based on what is at stake in the game.

It is important to consider how the results of the present study transfer to other contexts. The results suggest that a child's social interactions are often also affected by the social context, such as the other participating children in the conversation, or even the type of task. As described in previous works, it is within varying social contexts that children practice and learn their social competencies [22, 28]. Within these different contexts, children are enabled to practice various social interactions, appropriate to the context. Therefore, the findings of this study may not be directly applicable to all other cooperative video games, for instance.

Additionally, in online video games we often observe the 'online disinhibition effect,' where the anonymity of the online setting makes players feel less restrained to express themselves more openly [58]. Although Ruby's Mission was tested in a co-located setting, it was designed as an online multiplayer video game. It is interesting to investigate *if* and *how* the quantitative and qualitative social interactions of children change when the game is played as an online game. The differences may improve our understanding on how the differences between offline and online interactions.

In the present study we have combined different approaches to investigate children's socioemotional skills and their social interactions. Aside from using questionnaire data on the self-reported socioemotional skills, we have also adopted an observational approach from conversation analysis, namely the stimulus-response model to categorize verbal communication. We applied this approach on naturalistic data (i.e., audio recordings) to analyze the children's real-time social interaction, an approach discussed in Reeves et al. [44]. We believe that annotations of real-time behaviour using naturalistic data may reveal additional insights into the real-time (social) processes at hand during gameplay.

In this study, we examined children's verbal communicative behavior while they played a video game with clear rules and objectives. While one might argue that the observed behavior is more structured because the given tasks and assignments are related to training socioemotional skills, we contend that we were still observing children's natural behavior during gameplay in an online multiplayer environment. Although the in-game tasks are structured, the interactions themselves remain unstructured.

7 Conclusion

The present study is one of the first to explore how children's socioemotional skills relate to their real-time social interactive behaviour within an online multiplayer video game context. While video games are sometimes criticized for their social impacts, research has increasingly demonstrated their potential to serve as positive environments for social, emotional, and cognitive development [23], particularly when games are designed to promote prosocial behaviour [21]. Therefore, understanding these real-time digital interactions may be an important first step to eventually understand how these skills lead to better social life outcomes. We did find that socioemotional skills do indeed predict how verbal communication unfolds during social interaction in online multiplayer video games. Nevertheless, other factors such as personality traits, social familiarity, and group size also appeared as predictors of the verbal communication patterns. Furthermore, the results affirm that the social context is crucial in shaping these dynamics. Further research could explore more complex measures of interaction, how these apply to different contexts, and how these contribute to the long term development of children's social development.

Author Contributions

Dionysis Alexandridis: Experimentation, Conceptualization, Writing – original draft, review and editing. **Gijs A. Holleman:** Formal analysis, Conceptualization, Writing – original draft, review and editing. **Anouk Vroegindeweij:** Formal analysis, Writing – original draft and review. **Lisa Levelt:** Formal analysis, Writing – original draft and review. **Elise M. van de Putte:** Writing – review. **Remco C. Veltkamp:** Writing – review. **Sanne L. Nijhof:** Writing – review. **Sander C. J. Bakkes:** Writing – review and editing.

Declaration of Competing Interests

The authors declare that they have no conflicting interests.

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A Supplementary Materials

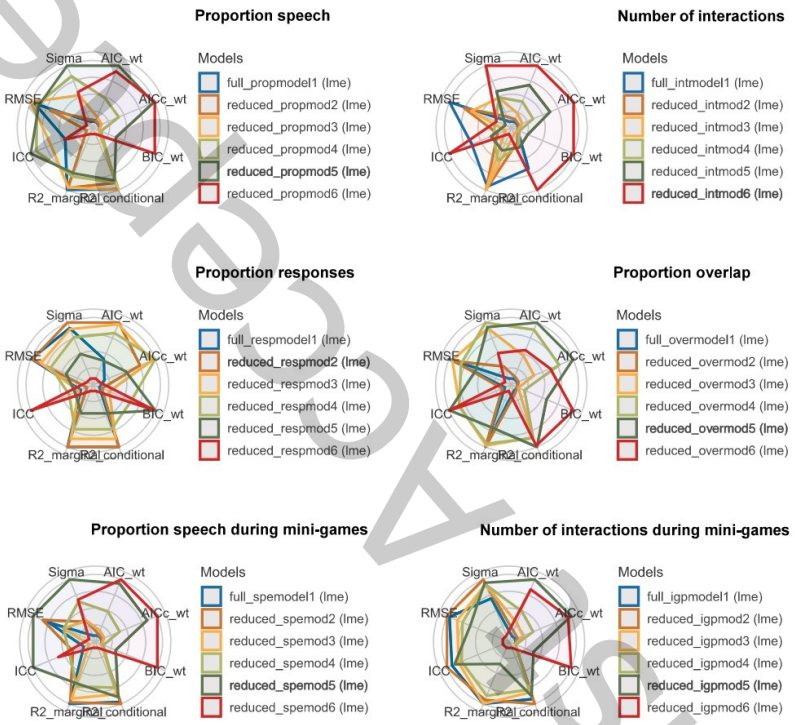

Fig. 4. Comparison of model performance indices for each outcome.

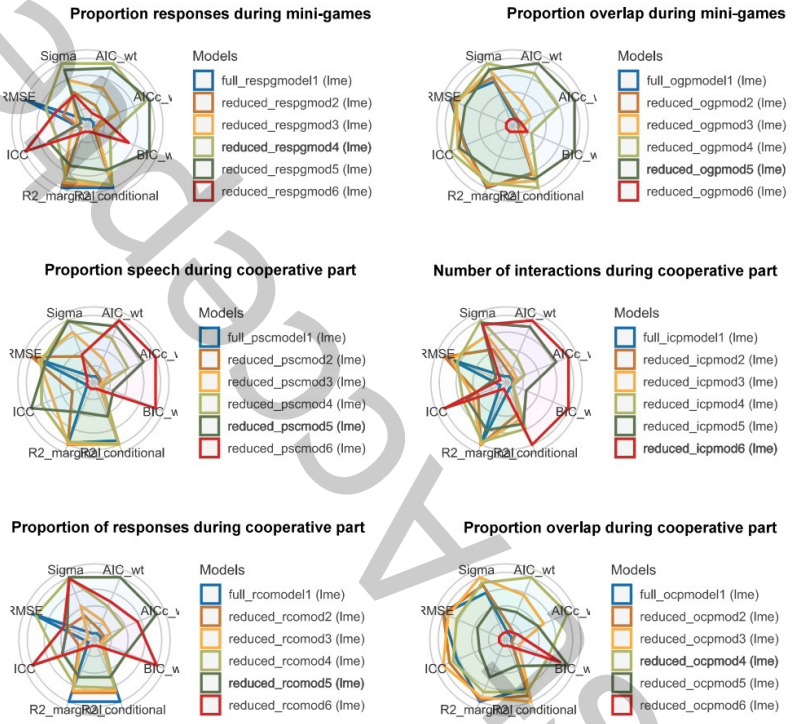

Fig. 5. Comparison of model performance indices for each outcome, continued.

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