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REVIEWED BY
Stella Tsotsi,
Oslo Metropolitan University, Norway
Kay Brauer,
Martin Luther University of
Halle-Wittenberg, Germany

*CORRESPONDENCE
Corina Wustmann Seiler
✉ corina.wustmann@phzh.ch

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Developmental trajectories of children's playfulness in two- to six-year-olds

Corina Wustmann Seiler^{1*}, Isabelle Duss², Cornelia Rüdüsüli¹ and Patricia Lannen²

¹Zurich University of Teacher Education, Zürich, Switzerland, ²Marie Meierhofer Children's Institute (MMI), Associated Institute of the University of Zurich, Zürich, Switzerland

Even though playfulness has been found to be highly relevant to the development and wellbeing of young children, hardly any longitudinal findings are available on stability and changes in children's playfulness. This study examined developmental trajectories of children's playfulness in two- to six-year-olds over a two-year period and analyzed whether individual and family characteristics and transition to primary school explain these trajectories. The sample included 839 children (47.3% girls, $M_{Age} = 4.87$ years, $SD_{Age} = 1.39$) from 38 childcare centers and 47 kindergartens in Switzerland. Children's playfulness was assessed at three measurement time points at one-year intervals using the multidimensional Children's Playfulness Scale to gather parent and teacher reports. Second-order linear growth curve models showed significant interindividual differences in children's playfulness at initial baseline. These differences correlated with effects for age, migrant background, and maternal education. The growth-related processes varied depending on children's age, and the individual dimension of children's playfulness whether an increase, stability, or decline was observed. In particular, social components of playfulness were found to change. On average, children's playfulness increased in early years but decreased from school age onwards. However, closeness in parent-child relationships proved to be supportive of children's playfulness at all time points. The results indicate the significance of positive parenting to children's playfulness, but they also draw attention to how playful qualities can be maintained and more highly valued in the school environment. In general, the study can contribute to a better understanding of the construct of playfulness in childhood.

KEYWORDS

playfulness, children, longitudinal study, latent growth curve models, parent-child relationship, transition to school

Introduction

Current literature on play suggests that how a child approaches play is more important than the play activity itself (Barnett, 2018; Chiarello et al., 2019). This playfulness, or playful behavior, is understood as the quality of a child's play (Lieberman, 1965), their disposition to engage in play (Barnett, 1991b), and the attitude, essence, and spirit of children's play (Bundy, 1997). Playful children are characterized by spontaneity, activity, and flexibility in their play (Skard and Bundy, 2008). Because young children learn through play (Zosh et al., 2017), a general assumption is that when a child is playful, they can better learn through active experiences with others and with materials

and that this benefits children's development and health (Waldman-Levi et al., 2022). Playful learning harnesses the power of focused, engaged, meaningful, socially interactive, joyful, and iterative thinking and learning in a way that leads to more effective learning processes and can therefore be seen as a resource essential to lifelong learning (Zosh et al., 2018).

Though much has been published on children's play, its development, and its significance for child development, we know relatively little about how playfulness develops in childhood, what promotes or inhibits its development, and whether its trajectories vary interindividually (Barnett, 2018). These developmental processes have hardly been investigated to date, as it was previously assumed that children's playfulness is stable across time and contexts (Barnett, 1991a). Additionally, most studies have been conducted in early childhood, from birth to 6 years, and rarely in the transition to school age. The present study addressed this desideratum and investigated developmental trajectories of playfulness in children aged 2–6 years over a two-year period with three measurement time points at one-year intervals. In addition, this study for the first time analyzed as predictors in the long term the individual characteristics of age and gender; the family characteristics of number of siblings, birth order, migrant background, maternal education, and parent-child relationship; and entry to formal primary school. Currently, only cross-sectional studies have been published on the relationships between these determinants and children's playfulness (e.g., Barnett and Kleiber, 1984; Rentzou, 2013).

Theoretical assumptions of children's playfulness

To date, children's playfulness has been theorized in two main approaches: as a stable, internal predisposition and a behavior trait, or as a dynamic capacity which is influenced by internal and external factors in transactions between child, play, and environment (e.g., Bronson and Bundy, 2001; Keleş and Yurt, 2017; Waldman-Levi et al., 2022). The first assumption stemmed mainly from descriptions of children being playful, which are ascribed to such personality attributes as bright, affectionate, confident, easy-going, innovative, cheerful, curious, and imaginative (Lieberman, 1977; Barnett, 1991a). In addition, test–retest analyses proved to be highly correlated, and playfulness was interpreted as a stable construct, maintained characteristic approach, or play style of the child (Trevlas et al., 2003). The idea that children's playfulness may be more variable arose from evidence that contextual factors are associated with and can promote playfulness, such as the quality of relationships with and play support from parents and teachers (e.g., Bundy et al., 2008; Pinchover et al., 2016; Waldman-Levi, 2021; Wu et al., 2024). In addition, some studies have shown that interventions can be effective in improving playfulness in young children (Okimoto et al., 2000; Skaines et al., 2006; Wilkes-Gillan et al., 2016). Cornelli Sanderson (2010) theorized that the construct of playfulness may comprise two inter-related components, a stable behavior trait and a capacity for play whose expression is context dependent.

Multidimensionality of children's playfulness

Working from the theoretical and observation-based empirical work of Lieberman (1965, 1977), Barnett (1990) described children's playfulness operationally as displaying five components, which underlie the questionnaire-based Children's Playfulness Scale (CPS; Barnett, 1991b): manifest joy, spontaneity in cognitive, social, and physical functioning, and sense of humor. Manifest joy is presented by the degree of exuberance, joy, enthusiasm, and heightened positive emotions the child exhibits in play. Cognitive spontaneity encompasses the degree to which imagination and creativity are shown in play by the child inventing roles and characters. Social spontaneity captures the child's ability to move in and out of social play situations fluidly, to share, and to show leadership during peer play. Sense of humor includes the teasing, rhyming, humor appreciation, and joke-telling aspects shown during play. Physical spontaneity reflects the child's activity level and physical coordination during play.

Lieberman (1977) conceptualized the five dimensions as theoretically equivalent and stated that playfulness relates to creativity, imagination, and curiosity, which lie behind these five facets. However, this assumption has been criticized somewhat. Shen et al. (2014) assumed that cognitive spontaneity is responsible for spontaneous expressions in physical behavior and social contexts. Proyer and Brauer (2023) stated that the dimension of manifest joy might also be a consequence of being playful, because playfulness predicts positive emotions. The same distinction between structure and consequence of playfulness is assumed to apply to humor and creativity (Proyer, 2018; Proyer et al., 2019). Bundy et al. (2001) found that the inclusion of physicality as part of the spontaneity dimension makes the CPS inappropriate for physically disabled children.

Skard and Bundy (2008) therefore developed the Test of Playfulness (ToP) in the field of occupational therapy as an alternative measurement instrument for assessing children's playfulness in the following four dimensions, independent of physical facets: intrinsic motivation (ability to engage in self-chosen, meaningful play activities), internal control (ability to change play to create more fun or challenge or to persist despite encountering personal or environmental challenges), freedom to suspend reality (ability to determine how close to objective reality a play transaction will be or engaging in joking or mischievous behaviors), and framing (ability to provide and read cues that indicate how a player wants to be treated during the play and that support the continuation of play; Waldman-Levi et al., 2022). These dimensions are closely linked to the dimensions of the CPS (Barnett, 1991b; Bundy et al., 2001; Muys et al., 2006). The ToP uses a 15-min observation while the child is engaged in free play. It is therefore more likely to be used in clinical research with small samples and is usually rated by trained external observers.

The multidimensional nature of playfulness can also be found in more recent works: In their interdisciplinary review, Masek and Stenros (2021) identified six fundamental themes of playfulness across all age groups and measurement instruments: (1) being willing to engage in a high degree, (2) open to many contexts and flexible even when the experience is complicated or ambiguous, (3) able and willing to alter a context to increase engagement

for themselves or others, “framing or re-framing,” (4) intrinsically motivated and engaged without having an expected outcome, (5) imagining an alternative reality, and (6) being or acting unconventionally. Similarly, [Shen et al. \(2014\)](#) synthesized three core characteristics of playfulness from all existing definitions and instruments, which are common to all: intrinsic motivation, freedom, and spontaneity.

Development of playfulness in childhood

To the best of our knowledge, only two longitudinal studies have been conducted on playfulness in childhood in typically developing children. [O'Brien and Shirley \(2001\)](#) investigated children's playfulness over 4 years and found it to remain constant, but their study is based on an extremely small sample size ($N = 5$ children) using video analyses with the ToP and does not include further child characteristics. [Waldman-Levi et al. \(2022\)](#) examined playfulness in 86 children from infancy at 6 months to toddlerhood at 24 months, also with the ToP. The authors found children's playfulness increasing over the 18 months and mediated by cognitive functioning, which suggests that cognitive skills contribute to the development of children's playfulness.

Findings from cross-sectional studies have not been entirely consistent regarding the role of children's age within the preschool range. Most studies examined children aged between 18 months and 6 years. Many studies reported higher scores in playfulness in older children, both globally and in its individual dimensions, particularly in cognitive, social, and physical spontaneity ([Barnett, 1991a](#); [Cornelli Sanderson, 2010](#); [Bay, 2021](#); [Ata and Macun, 2022](#)). However, some studies have found higher scores in younger children: for the ToP rated in three- to five-year-olds reported by [Saunders et al. \(1999\)](#), and for the social spontaneity dimension of the CPS rated in children aged between 16 to 62 months reported by [Rentzou \(2013\)](#). The reasons for these age differences are seen in children's growing capacity to play independently, their broader play repertoires, and their increasing social-emotional and cognitive competences over time, including their growing ability to direct play with others and to regulate emotions during free play ([Cornelli Sanderson, 2010](#)).

But there are hardly any studies that follow children to school age. [Barnett \(2018\)](#) noted that the primary school setting contrasts strongly with the preschool or family setting because it is more structured, regulated, and controlled and children have less time for play. The transition to school is also a critical life event accompanied by numerous challenges and transformations, such as new social relationships, a new identity as a school child, and new school demands ([Balduzzi et al., 2019](#)). Furthermore, there is evidence that play generally declines with age and decades ([Elkind, 2008](#); [Gray, 2011](#); [Mullan, 2019](#)). The reasons are mainly seen in more time spent at school, more structured leisure activities, more screen time, and fewer outdoor activities.

Children's playfulness and gender

The role of gender has been the individual characteristic most studied in research on children's playfulness to date. However,

heterogeneous patterns have been found. [Zachopoulou et al. \(2004\)](#) reported that boys had higher scores on three dimensions of children's playfulness than girls: physical spontaneity, manifest joy, and sense of humor. Similar results were found by [Barnett \(1991a\)](#) and [Mabagala \(2016\)](#) and, for the physical spontaneity dimension, by [Mouratidou et al. \(2023\)](#). [Saunders et al. \(1999\)](#) and [Cornelli Sanderson \(2010\)](#) found that girls were rated higher on global playfulness than boys. [Keleş and Yurt \(2017\)](#) found that girls scored higher on social spontaneity, but [Mouratidou et al. \(2023\)](#) was recently unable to confirm this finding: in their study, boys showed higher scores. In contrast, other studies have found no differences between girls and boys ([Rentzou, 2013, 2014](#); [Bay, 2021](#); [Ata and Macun, 2022](#); [Fung and Chung, 2022](#)).

It is possible that these heterogeneous findings stem from the different measurement instruments that were used, different informants reporting on children's playfulness, and girls' and boys' differing cultural values, perceptions, and role expectations ([Cornelli Sanderson, 2010](#)). This begs the question whether caregivers consider the facets of children's playfulness as different in girls and boys. A study by [Barnett \(2018\)](#) provides some evidence on this: Teachers rated playful boys as increasingly negative, rebellious, and intrusive, labeled them “class clowns,” and tended to stigmatize them from grades 1 to 3; but their classmates initially experienced playful boys as appealing and engaging playmates. A vicious cycle results that ultimately has an unfavorable effect on the boys' relationships with peers, who assimilate the teachers' signals, and on their own positive self-perception.

Children's playfulness and family characteristics

To date, studies concerning the effects of sociodemographic and family characteristics on children's playfulness are rather sparse and heterogenous, and all stem from cross-sectional studies. The main focus has been on the role of siblings in birth order and number; the socio-economic background of the family, measured by socio-economic status (SES) and parental education; and the parent-child relationship ([Barnett and Kleiber, 1984](#); [Rentzou, 2013](#); [Wu et al., 2024](#)).

Siblings

[Barnett and Kleiber \(1984\)](#) and [Barnett \(1991a\)](#) found later-born male siblings, boys who have more sisters, and girls who have fewer sisters to be more playful. [Rentzou \(2013\)](#) reported significant positive correlations between all dimensions of children's playfulness and birth order. [Keleş and Yurt \(2017\)](#) found no significant effect of birth order; however, the number of siblings was related to social spontaneity and manifest joy, such that children with two or more siblings had lower scores than children with one sibling. [Ata and Macun \(2022\)](#) came to similar results when comparing children with one sibling to children with two or more siblings. In contrast, [Bay \(2021\)](#) found no significant effect of the number of children in the family. These heterogenous results could indicate that social play experiences with siblings may vary, possibly depending on the age of the children, the siblings' distance, and the siblings' level of playfulness and social skills.

Socioeconomic background

Barnett and Kleiber (1984) found a significant positive relationship between family socioeconomic status and playfulness in girls, but not in boys. Ata and Macun (2022) found a significant effect of family income, with children in families with higher incomes reported as more playful. No significant results were found for parental work status (Bay, 2021; Ata and Macun, 2022), parental educational level (Bay, 2021), or migrant background (Rentzou, 2013).

Parent–child relationship

Studies have indicated positive relationships between children's playfulness and caregivers' sensitivity and responsiveness (Chiarello et al., 2006; Fabrizi et al., 2016), parental play supportiveness (Waldman-Levi, 2021; Fung and Chung, 2022), a democratic parenting style, and close parent–child relationships (Wu et al., 2024). In contrast, negative correlations were found for high-conflict parent–child relationships (Wu et al., 2024). Gordon (2014) theorized that playfulness depends on secure attachment relationships: securely attached children see the world as a playground and explore it with enthusiasm. According to this approach, the development of playfulness in children is assumed to be closely linked to positive parenting, from which other significant interpersonal experiences are formed across various social contexts (Youell, 2008).

Summary and present study

Although playfulness is presumed to be of great importance for the development and wellbeing of young children, longitudinal research on stability and change over time in children's playfulness is scarce (Keleş and Yurt, 2017). However, as Waldman-Levi et al. (2022) recently noted, “a predisposition is a tendency, not an invariant quality” (p. 2). Whether and how playfulness develops in childhood in a longitudinal perspective cannot be answered adequately with the knowledge currently available. Most of the previous studies have been cross-sectional correlational studies. Barnett (2018) summarized a pressing need to examine these developmental processes to enable greater precision in describing and discussing the underlying construct. Given that the construct of playfulness encompasses cognitive, social, emotional, and physical elements in children's play behavior, the various facets may develop differently. This is of high significance not only for further research into the construct but also for practical implications about how playfulness can be promoted in children and which dimensions can be supported in the long term. Furthermore, very few studies have examined children's playfulness during transition to school age.

Finally, multi-informant approaches that consider different perspectives on children's playfulness, such as in the family and in extrafamilial settings, are crucial but rarely available. In most studies, children's playfulness was exclusively assessed by teacher ratings using the CPS (Cornelli Sanderson, 2010). Parents' ratings were used less frequently. However, Rigby and Gaik (2007) found that children tend to be more playful at

home than at school. Children may play differently depending on contexts, and parents and teachers have different perspectives and motivations for their ratings of a child. Both see the playing child in different play environments and can therefore add to a broad and valid global characterization of the child's play (Rentzou, 2013). By averaging the ratings of parents and teachers, biases can be minimized.

The aim of the present study was to examine developmental trajectories in children's playfulness with a multi-informant approach using teacher and parent ratings over a period of 2 years in two- to six-year-old children. In addition, individual and family characteristics and children's transition to formal primary school were considered as predictors of these trajectories. Therefore, the following research questions were addressed:

- (1) How does children's playfulness change in two- to six-year-olds over a period of two years?
- (2) What effects do individual and family characteristics have on the developmental trajectories of children's playfulness in two- to six-year-olds?
- (3) What effect does primary school attendance have on children's playfulness?

In the present study, children's age and gender were included as individual determinants. Birth order, number of siblings, migrant background, and maternal education were entered as stable family characteristics, whereas the quality of parent–child relationships, measured as closeness and conflict, was considered as a time-varying predictor in the family environment. Parent–child relationships were also evaluated in a longitudinal perspective. Entry to formal primary school was also applied as time-varying. Due to the heterogeneous and limited state of research, no directional hypotheses were formulated about stability and changes over time in children's multidimensional playfulness; instead, developmental trajectories were investigated exploratorily. The same applied to longitudinal prediction by gender, birth order, number of siblings, migrant background, and maternal education. However, from the reviewed literature above, children's playfulness was assumed to increase with age, as their play repertoires and their cognitive and social-emotional competencies and skills grow. In addition, a close parent–child relationship can be expected to have a positive effect on children's playfulness at all time points, as it provides secure social experiences in childhood, whereas entering the formal school setting has a negative effect, as children have less time for free play and are challenged by school demands, rules, structures, and formal learning processes.

Materials and methods

Procedure

The present longitudinal study was part of a project titled “Playfulness in Early Childhood (Playful)” and funded by the Swiss National Science Foundation. Participants were recruited through institutions of early childhood education and care (ECEC): childcare centers and kindergartens across Switzerland. In Switzerland, childcare centers are private institutions for

children from infancy to kindergarten. Kindergarten is part of the public school system; it is mandatory for children from the age of four and typically lasts 2 years. After these 2 years, children start primary school. In both childcare centers and kindergartens, a lot of time during the day is devoted to free play. When recruiting the sample, we considered urban and rural areas and various cantons. Children's playfulness was assessed at three measurement time points with a one-year interval (T1, spring 2021; T2, spring 2022; T3, spring 2023) using an online questionnaire to gather parent and teacher reports. Individual and family characteristics were also surveyed using the parent questionnaire at T1. Time-varying parent-child relationship quality was assessed at all three measurement time points. At T2 and T3, information about the child's transfer to another ECEC institution or entry into formal primary school was provided by the parents. The online questionnaires were administered with Survalyzer software.

The Ethics Committee of the Faculty of Philosophy at the University of Zurich, Switzerland, reviewed and approved the study (ethics approval number 20.12.13). Parents and teachers were informed about the aims and procedures of the study by a written study description and provided their written consent for participation. They were also informed about their right to withdraw from the study at any time without stating a reason. Additionally, parents and teachers were advised that data would be stored on a secure server in anonymized form and used exclusively for research purposes.

Sample

The sample consisted of 839 children between 2 and 6 years ($M_{Age} = 4.87$, $SD_{Age} = 1.39$; 47.3% girls) distributed over 38 childcare centers and 47 kindergartens in 12 German-speaking cantons in Switzerland. Of the children, 242 (28.8%) were 2 and 3 years old, 373 (44.5%) were 4 and 5 years old, and 224 (26.7%) were aged 6 years at T1. The average number of children participating in each ECEC group or class was 10 children. Some 44.3% of the children attended a childcare center, and 55.7% a kindergarten at T1. The time children spend in kindergarten is usually spread over five mornings (8 am to 12), whereas children spend fewer days but more hours in childcare centers, usually two and a half to three full days per week (Bundesamt für Statistik, 2021). In the first years of primary school in Switzerland, children usually have lessons in the morning between 8am and 12 (4 lessons) and one to two afternoons with two lessons. Free play is often only spread over break times or individual lessons.

Most children were of Swiss origin (82.1%; 17.9% had another nationality, mostly European, e.g., Germany, Italy, or Serbia), lived with both parents at home (nuclear family, 94.8%), and had siblings (84.1%), mostly one (70.8%) or two (22.3%). At T2, 1 year later, 747 children ($M_{Age} = 5.85$, $SD_{Age} = 1.40$; 46.7% girls) participated in the study (participation rate 89.0%). Finally, at T3, 2 years after T1, 691 children, now between 4 and 8 years ($M_{Age} = 6.87$, $SD_{Age} = 1.41$; 47.8% girls), took part in the long-term study (92.5% of those participating at T2). At T3, 58.8% of the children were in primary school. The parent questionnaire was mostly completed by the mothers (T1, 83.0%; T2, 84.6%; T3, 85.8%). More information

TABLE 1 Sample characteristics at three measurement time points (T1–T3).

	T1 N = 839	T2 N = 747	T3 N = 691
Gender (girls)	397 (47.3%)	349 (46.7%)	330 (47.8%)
Local language at home (German)	657 (88.9%)	603 (89.6%)	575 (90.6%)
First-born child	262 (44.0%)	236 (43.4%)	227 (43.6%)
Mother with an academic degree	413 (60.2%)	382 (60.4%)	365 (61.2%)
Educational setting			
Childcare center	372 (44.3%)	258 (34.5%)	94 (13.6%)
Kindergarten	467 (55.7%)	315 (42.2%)	180 (26.0%)
Primary school	—	173 (23.2%)	406 (58.8%)
Other ^a	—	1 (0.1%)	11 (1.6%)
Return rates of questionnaires			
Parents	88.8%	77.1%	83.1%
Teachers	91.4%	82.3%	67.6%

Number and/or percentage values.

^ae.g., special education schools.

regarding the demographic characteristics of the sample at T1–T3 can be found in [Table 1](#).

Dropout rates were moderate: 148 children (17.6%) left the study between T1 and T3. This was due to random dropouts of individual children changing ECEC groups or classes, children moving away, and parents and/or new teachers refusing to participate in the study and withdrawing from it. Analyses of dropouts showed no significant differences in children's playfulness scores when comparing children who participated in both T1 and T2 with those who participated in T1 only, and children who participated in all three measurement time points with those who participated in T1 and T2 only. The same applied to demographics and parent-child relationship scales. All details on dropout analysis are reported in [Table 2](#).

Study measures

Children's playfulness

Parents and teachers completed the German version of the Children's Playfulness Scale (CPS; [Barnett, 1991b](#); [Wustmann Seiler et al., 2021](#)) for a multi-informant rating at all three measurement time points. The CPS is used internationally as a reliable and valid instrument for assessing children's playfulness in two- to twelve-year-olds (see, e.g., [Rentzou, 2013](#); [Mabagala, 2016](#); [Keleş and Yurt, 2017](#); [Barnett, 2018](#)). The scale consists of 23 items in total, rated on a five-point Likert scale ranging from 1 (doesn't sound at all like the child) to 5 (sounds exactly like the child), with five dimensions: manifest joy (5 items, e.g., "My/the child expresses enjoyment during play."), cognitive spontaneity (4 items, e.g., "My/the child invents his/her own games to play."), social spontaneity (5 items, e.g., "My/the child responds easily to others' approaches during play."), sense of humor (5 items, e.g., "My/the child enjoys joking with other children."), and physical spontaneity (4 items, e.g.,

TABLE 2 Analysis of dropouts between the three measurement time points (T1–T3).

	Participation at T1 and T2 compared to T1 only	Participation at T1, T2, and T3 compared to T1 and T2 only
Total playfulness score	$\beta = 0.05, p = 0.277$	$\beta = -0.03, p = 0.514$
Demographics		
Age	$\beta = -0.03, p = 0.567$	$\beta = 0.05, p = 0.223$
Gender	$\beta = -0.03, p = 0.337$	$\beta = 0.03, p = 0.447$
Birth order	$\beta = -0.04, p = 0.362$	$\beta = -0.03, p = 0.459$
Migrant background	$\beta = -0.07, p = 0.147$	$\beta = -0.08, p = 0.137$
Maternal education	$\beta = 0.02, p = 0.696$	$\beta = 0.04, p = 0.305$
Parent–child relationships		
Closeness	$\beta = -0.04, p = 0.307$	$\beta = 0.07, p = 0.165$
Conflict	$\beta = -0.02, p = 0.539$	$\beta = 0.03, p = 0.467$

β , Standardized regression coefficient.

“My/the child is physically active during play.”). Items rated by parents and teachers were averaged. Parent and teacher reports showed significant positive correlations ($r_{T1/T2/T3} = 0.23/0.16/0.25$ for the total playfulness score).

Confirmatory factor analyses (CFA) were conducted to analyze the five-dimensional structure. To reduce the complexity of the model and to use exactly three indicators for each latent variable (Little, 2013), we decided to include only those items per dimension that offered high factor loading and satisfactory reliability. The resulting longitudinal CFA model with five latent variables, each with three indicators, fitted the data acceptably [$\chi^2[791] = 1,441.39, p < 0.001, CFI = 0.954, RMSEA = 0.031, SRMR = 0.044$]. Two error correlations were allowed for T1 and one each for T2 and T3 between two items of the physical spontaneity and sense of humor dimensions and two items of the manifest joy dimension, respectively. McDonald's omega reliability values were found to be satisfactory for all five factors and all time points (manifest joy, $\omega_{T1/T2/T3} = 0.74/0.76/0.79$; cognitive spontaneity, $\omega_{T1/T2/T3} = 0.71/0.72/0.74$; social spontaneity, $\omega_{T1/T2/T3} = 0.82/0.82/0.78$; sense of humor, $\omega_{T1/T2/T3} = 0.81/0.82/0.76$; physical spontaneity, $\omega_{T1/T2/T3} = 0.84/0.85/0.83$). To arrive at a total playfulness score, a CFA was conducted using the mean values of the five dimensions modeled as manifest indicators of the latent total playfulness factor. The longitudinal CFA model fitted the data well [$\chi^2 [72] = 200.78, p < 0.001, CFI = 0.966; RMSEA = 0.046; SRMR = 0.049; N = 839$], and the total playfulness scores showed sufficient internal consistency for all time points (McDonald's Omega $\omega_{T1/T2/T3} = 0.78/0.78/0.78$). Descriptive statistics for the five dimensions and the total scores are reported in Table 3 separately for the total sample and differentiated by three age groups.

Measurement invariance over time was tested by comparing several invariance models, a configural model with unconstrained item loadings and intercepts to a metric invariance model with item loadings constrained to equality, and the metric model to a scalar invariance model with item intercepts constrained to equality (Cheung and Rensvold, 2002). Because scalar invariance is often difficult to realize in practice, partial scalar invariance applying to at least two items per factor is also considered acceptable

for longitudinal models (Byrne et al., 1989). In the present analyses, models were compared using chi-square difference tests with a Satorra-Bentler correction (Satorra and Bentler, 2001). Measurement invariance results are reported in Table 4. Results showed evidence of a partially scalar invariance for all latent factors with only two to three item intercepts constrained to equality. These findings indicated that the requirements for longitudinal analysis of latent mean values are generally met, and the measures' meaning is equivalent across time (Putnick and Bornstein, 2016).

Individual characteristics

Age and gender (1 = girls, 0 = boys) of the child were collected via parent questionnaires at T1.

Family characteristics

Child's birth order was operationalized at T1 as a dichotomous variable with 1 = first-born and 0 = second- or later-born. The number of siblings ranged from 1 (1 sibling) to 6 (>5 siblings). Children without siblings were classified as missing. Migrant background was defined by the language spoken at home and dummy coded as 1 = German as a second language at home and 0 = local language at home (Swiss German or German). Maternal education was assessed as an indicator of the family's socioeconomic status. It was entered as a dummy coded covariate in relation to an academic degree at a university, a university of teacher education, or a university of applied sciences at T1 (1 = academic degree, 0 = no academic degree).

Parent–child relationship quality was measured using the short form of the Child–Parent Relationship Scale (CPRS-SF; Pianta, 1992) in the German adaptation by Dobliger (2018). The scale is a five-point Likert scale ranging from 1 (definitely does not apply) to 5 (definitely applies) and captures parents' perceptions of their relationship with their child. It is a widely used, 15-item self-report instrument that captures both positive and negative aspects of parent–child relationships with two scales: level of closeness and conflict (Driscoll and Pianta, 2011). The closeness scale measures

TABLE 3 Descriptive statistics of children's multidimensional playfulness at three measurement time points (T1–T3) differentiated by children's age at T1.

	Total sample 2–6 years (n = 839)			Subsample 2–3 years (n = 242)			Subsample 4–5 years (n = 373)			Subsample 6 years (n = 224)		
	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)
MJ	4.24 (0.42)	4.28 (0.45)	4.24 (0.47)	4.16 (0.43)	4.25 (0.50)	4.31 (0.51)	4.26 (0.40)	4.33 (0.41)	4.27 (0.40)	4.30 (0.41)	4.21 (0.43)	4.14 (0.52)
CS	4.03 (0.56)	4.09 (0.60)	4.05 (0.64)	3.70 (0.57)	4.01 (0.65)	4.17 (0.65)	4.13 (0.54)	4.21 (0.61)	4.11 (0.64)	4.20 (0.47)	4.03 (0.50)	3.94 (0.54)
SS	3.78 (0.65)	3.90 (0.64)	4.01 (0.63)	3.50 (0.62)	3.80 (0.64)	4.04 (0.62)	3.88 (0.55)	3.96 (0.62)	3.99 (0.63)	3.90 (0.73)	3.89 (0.64)	4.02 (0.59)
SH	3.40 (0.67)	3.58 (0.65)	3.63 (0.59)	3.02 (0.70)	3.47 (0.70)	3.69 (0.57)	3.48 (0.65)	3.64 (0.65)	3.60 (0.63)	3.67 (0.49)	3.60 (0.56)	3.61 (0.51)
PS	4.10 (0.62)	4.14 (0.66)	4.10 (0.64)	3.98 (0.63)	4.06 (0.60)	4.11 (0.61)	4.10 (0.64)	4.26 (0.63)	4.15 (0.67)	4.21 (0.54)	4.05 (0.71)	4.03 (0.61)
TPS	4.39 (0.41)	4.42 (0.42)	4.41 (0.42)	4.26 (0.40)	4.39 (0.44)	4.49 (0.43)	4.40 (0.37)	4.47 (0.39)	4.42 (0.39)	4.49 (0.37)	4.35 (0.40)	4.32 (0.42)

Latent scores. MJ, manifest joy; CS, cognitive spontaneity; SS, social spontaneity; SH, sense of humor; PS, physical spontaneity; TPS, total playfulness score.

the extent to which a parent perceives that the relationship is based on warmth, affection, and open communication (7 items, e.g., “I share an affectionate, warm relationship with my child”). The conflict subscale assesses parents’ feelings and beliefs about the extent of conflicts in their relationship with the child (8 items, e.g., “My child and I always seem to be struggling with each other”). A longitudinal CFA confirmed the two-dimensional factor structure [$\chi^2[447] = 886.02, p < 0.001, CFI = 0.931, RMSEA = 0.038, SRMR = 0.079$]. However, four items had to be excluded due to low factor loadings (<0.40). The reliability of both scales was sufficient to good with McDonalds Omega ranging from 0.67 to 0.83 (closeness, 5 items, $\omega_{T1/T2/T3} = 0.67/0.74/0.74$; conflict, 6 items, $\omega_{T1/T2/T3} = 0.79/0.81/0.83$). In addition, preliminary measurement invariance tests revealed partial scalar invariance over time for both scales.

Primary school attendance

At T2 and T3, parents were asked what type of institution their child was attending at that time (“My child is currently attending primary school”). School attendance at T2 and T3 was then included as a dummy coded variable (1 = yes, 0 = no). When the parents were asked in spring 2022 (T2) whether their child was now attending primary school, the child had already been at school for more than 6 months (starting in August 2021). The same applied for T3. That means that the child had already settled into the school setting.

Statistical analyses

Developmental trajectories in children’s playfulness were analyzed with latent linear growth curve models (LGCMs) (e.g., Geiser, 2021) using Mplus version 8.8 (Muthén and Muthén, 1998–2022). LGCMs can be used to determine interindividual differences in the intercept (individuals’ initial starting point) and slope (rate of change over time) of individuals. In the present analyses, second-order linear growth models (SGMs) were applied (Sayer and Cumsille, 2001) in which the latent intercept and slope are estimated from latent variables. SGMs allow measurement error and measurement invariance to ensure that the same construct was measured identically in repeated measurements (Preacher et al., 2008). Furthermore, SGMs have more power to detect individual differences in change than do first-order latent growth curve models (von Oertzen et al., 2010). The mean of the latent intercept ($M_{Intercept}$) represents the average initial starting point in the sample, and the estimated variance of the latent intercept ($V_{Intercept}$) corresponds to interindividual variability in the baseline. The mean of the latent slope (M_{Slope}) indicates the average rate of change, and the estimated variance of the latent slope (V_{Slope}) represents the individual variability of changes over time.

First, unconditional SGMs were computed independently for the five dimensions and the total playfulness score to determine whether patterns of trajectories can generally be described as stable or changing and whether there are interindividual differences in the latent intercepts and slopes. For a more differentiated approach, we conducted these unconditional SGMs for the total sample of all two- to six-year-old children and for three groups based on

children’s age at T1, two- to three-year-olds, four- to five-year-olds, and six-year-olds. These age groups also represent different settings in Switzerland. Two- to three-year-olds are enrolled in childcare, four- to five-year-olds attend kindergarten, usually in their first year, and the six-year-olds are mostly in their second year of kindergarten and about to start primary school a few months later. Data collection for T1 took place in spring 2021, and the children aged 6 years started primary school in August 2021.

Second, conditional SGMs were analyzed, one for each dimension and one for the total score, in which individual and family covariates and primary school attendance were simultaneously added as manifest variables. Age, gender, and

migrant background were entered as individual covariates, and birth order, number of siblings, maternal education, and closeness and conflict in parent–child relationships were entered as family covariates. Closeness and conflict in parent–child relationships and school attendance were included as time-varying covariates with regression on the respective time point, and the other covariates were included as time-invariant and were only assessed at T1. All covariates were allowed to correlate with each other, and metric covariates were grand-mean centered. The evaluation of model fit was based on conventional goodness-of-fit criteria (e.g., Kline, 2015). A graphical representation of the statistical model described above can be found in Figure 1.

TABLE 4 Model fit comparison for the examination of measurement invariance in children’s multidimensional playfulness aged 2–6 years (N = 839).

	χ^2	df	p	CFI	RMSEA	SRMR	$\Delta\chi^2$	Δdf	p	ΔCFI	$\Delta RMSEA$	$\Delta SRMR$
Five-dimensional structure												
Configural	1,441.39	791	0.000	0.954	0.031	0.044						
Metric	1,465.37	811	0.000	0.954	0.031	0.047	23.98	20	0.181	0.000	0.000	0.003
Scalar	1,541.08	831	0.000	0.950	0.032	0.049	75.70	20	0.000	−0.004	0.001	0.002
Partial scalar ^a	1,485.47	828	0.000	0.953	0.031	0.048	20.10	17	0.235	−0.001	0.000	0.001
Total playfulness score												
Configural	200.78	72	0.000	0.965	0.046	0.049						
Metric	203.35	80	0.000	0.967	0.043	0.056	2.57	8	0.676	0.002	−0.003	0.007
Scalar	274.64	88	0.000	0.950	0.050	0.065	69.29	8	0.000	−0.017	0.007	0.009
Partial Scalar ^b	211.76	86	0.000	0.966	0.042	0.056	8.41	6	0.134	−0.001	−0.001	0.000

χ^2 , Chi-square; df, degrees of freedom; p, probability of type I error; CFI, comparative fit index; RMSEA, root mean square error of approximation; SRMR, standardized root mean square residual; Δ , difference value.

^aFreezing of three item intercepts (one item each on cognitive spontaneity at T2, social spontaneity at T3, and sense of humor at T3). ^bFreezing of two item intercepts (social spontaneity at T1 and sense of humor at T1).

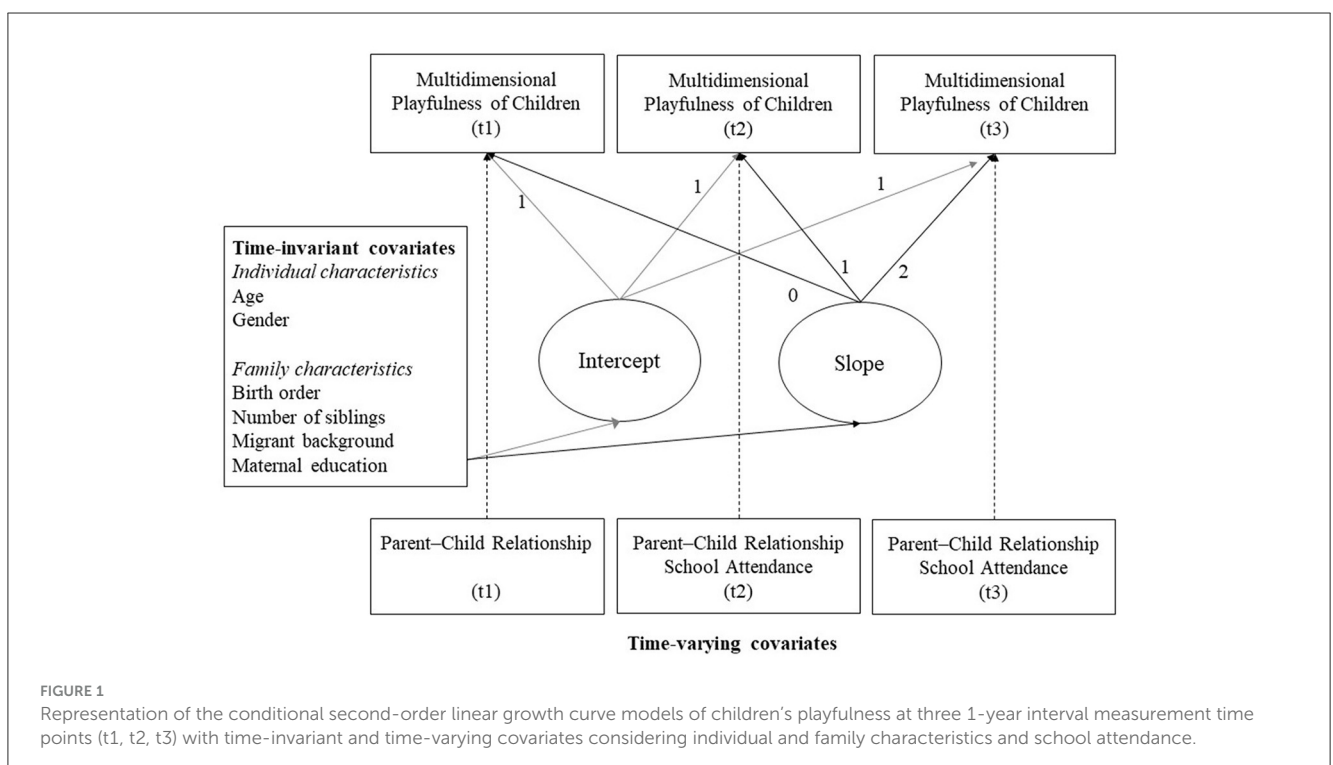


FIGURE 1 Representation of the conditional second-order linear growth curve models of children’s playfulness at three 1-year interval measurement time points (t1, t2, t3) with time-invariant and time-varying covariates considering individual and family characteristics and school attendance.

The multilevel data structure of children nested in ECEC groups or classes was accounted for using the Huber-White sandwich estimator (i.e., TYPE = COMPLEX option in Mplus; Freedman, 2006) because intraclass correlations (ICC) for children's playfulness scores varied between 0.05 and 0.17 and the design effect (DEFF) between 1.44 and 2.49 at T1. Model estimates thus considered the dependency of the observations within the ECEC groups or classes. Missing data were addressed using the full information maximum likelihood method.

Results

Descriptive statistics and intercorrelations between all study variables are presented in Table 5. Results of the unconditional SGMs analyzing developmental trajectories of children's playfulness in the total sample and the three age groups are outlined first, followed by the conditional SGMs pertaining to the effect of individual and family characteristics and school attendance on the developmental trajectories in children's playfulness.

Developmental trajectories in children's playfulness

All SGMs yielded adequate model fit, as presented in Table 6. Results on the average rate of change and on interindividual differences in the latent intercepts and slopes in children's playfulness are reported in Table 7.

Trajectories in the total sample of two- to six-year-olds

On average, latent intercepts in children's playfulness were relatively high in the total sample ($M_{\text{Intercept}} = 3.41\text{--}4.39$). The lowest intercept was found in the sense of humor dimension and the highest in manifest joy. However, significant interindividual differences in the intercepts were found in all five dimensions and the total playfulness score, indicating interindividual variability in the initial baseline of children's playfulness ($V_{\text{Intercept}}$). The highest differences were found in the social spontaneity and sense of humor dimensions and the lowest in the total playfulness score and the manifest joy dimension. The average rate of change (M_{Slope}) was positive for all scales but ranged from zero to very low ($M_{\text{Slope}} = 0.00\text{--}0.13$) and was only significant for the two dimensions of social spontaneity and sense of humor. The same applied for the total playfulness score, with an average rate of change close to zero. This indicated that the playfulness in the two- to six-year-olds on average neither increased nor decreased over the two-year period but remained stable.

However, significant interindividual differences in the latent growth curves were found in all five dimensions and the total playfulness score in the two- to six-year-olds (V_{Slope}), indicating that the development of children's playfulness varied between children. Statistically significant covariances ($r_{\text{Intercept/Slope}}$) between latent intercept and slope were also identified in all five dimensions except physical spontaneity and in the total playfulness score. All were negative, indicating that the rate of change was

higher in children with a low baseline and lower in children with a higher intercept.

Trajectories in different age groups

The three age groups exhibit different directions of change (see Table 7). Whereas all scores in children's playfulness increased significantly in the two- to three-year-olds ($M_{\text{Slope}} = 0.08\text{--}0.34$), they decreased in all dimensions except social spontaneity and in the total playfulness score in the six-year-olds, although not significantly in the sense of humor dimension ($M_{\text{Slope}} = -0.12\text{--}0.06$). For the four- to five-year-olds, by contrast, SGMs showed no significant average rate of change over time in the total playfulness score. In particular, the two dimensions of manifest joy and cognitive spontaneity proved to be stable in this age group. The other three dimensions increased slightly in the four- to five-year-olds ($M_{\text{Slope}} = 0.04\text{--}0.08$). Descriptive statistics reported in Table 3 indicated an increase in almost all dimensions from the first to the second measurement time point in this age group, but a decrease from the second to the third, and the same was the case for the total playfulness score. These results suggest that between the ages of six and seven, when the children are about 2 years older, children's playfulness seems to stop increasing and start decreasing. A graphical illustration of the trajectories in the total playfulness score across the three age groups can be found in Figure 2. Across all three age groups, the most significant change over time was found in the social spontaneity dimension.

Effects of individual and family characteristics

Standardized results of the conditional SGMs with the total sample of all children are reported in Table 8. Model fits were sufficient to very good. The covariates explained a maximum of 25% of the variance of the latent intercepts and 33% of the variance of the latent slopes in children's playfulness.

Effects on the latent intercepts (initial baseline)

In all dimensions and in the total playfulness score, older children were rated remarkably more highly than younger children, particularly in cognitive spontaneity, social spontaneity, and sense of humor. Girls had higher scores in cognitive spontaneity and social spontaneity and boys in physical spontaneity. First-born children had lower scores in social spontaneity than second- or later-born children, and the number of siblings was significantly negatively related to social spontaneity. Migrant background was linked to less manifest joy and less cognitive spontaneity. That means that a language other than Swiss German or German spoken at home led to lower-rated manifest joy and cognitive spontaneity in children. The same was the case for the total playfulness score; here, too, a small yet significant negative effect of migrant background was observed. Maternal education showed a small but significant positive effect on the intercepts for the cognitive spontaneity and sense of humor

TABLE 5 Intercorrelations and descriptive statistics of all study variables at three measurement time points (t1–t3).

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29				
1	MJ	t1	—																																
2	MJ	t2	0.47	—																															
3	MJ	t3	0.36	0.47	—																														
4	CS	t1	0.84	0.36	0.30	—																													
5	CS	t2	0.43	0.79	0.44	0.50	—																												
6	CS	t3	0.32	0.39	0.74	0.37	0.61	—																											
7	SS	t1	0.48	0.15	0.16	0.47	0.15	0.11	—																										
8	SS	t2	0.18	0.38	0.27	0.18	0.41	0.21	0.61	—																									
9	SS	t3	0.22	0.19	0.51	0.21	0.23	0.39	0.48	0.62	—																								
10	SH	t1	0.66	0.34	0.25	0.72	0.34	0.21	0.44	0.19	0.14	—																							
11	SH	t2	0.34	0.74	0.36	0.32	0.68	0.29	0.14	0.36	0.20	0.48	—																						
12	SH	t3	0.28	0.37	0.78	0.26	0.43	0.68	0.15	0.21	0.43	0.35	0.49	—																					
13	PS	t1	0.61	0.32	0.25	0.40	0.15	0.07	0.17	0.00	0.08	0.49	0.28	0.25	—																				
14	PS	t2	0.27	0.63	0.27	0.14	0.34	0.07	−0.02	0.09	0.01	0.27	0.51	0.24	0.54	—																			
15	PS	t3	0.27	0.35	0.56	0.16	0.19	0.35	0.04	0.06	0.14	0.21	0.31	0.50	0.50	0.62	—																		
16	Age	t1	0.16	0.01	−0.10	0.29	−0.06	−0.19	0.26	0.07	−0.01	0.33	0.05	−0.15	0.10	−0.02	−0.08	—																	
17	Gender	t1	0.02	0.00	−0.02	0.16	0.18	0.20	0.12	0.12	0.10	−0.02	−0.05	−0.04	−0.14	−0.23	−0.19	0.01	—																
18	Migrant	t1	−0.18	−0.07	−0.11	−0.18	−0.09	−0.14	−0.03	0.02	0.02	−0.11	−0.04	−0.09	−0.08	−0.04	0.00	−0.05	0.02	—															
19	First-born	t1	0.05	0.09	0.00	0.03	0.10	0.05	−0.09	−0.02	−0.07	0.00	0.04	−0.04	0.02	0.02	−0.06	0.07	−0.02	−0.03	—														
20	No. of siblings	t1	−0.03	−0.08	0.00	0.00	−0.08	−0.04	−0.01	−0.05	−0.03	0.06	−0.05	−0.03	0.07	0.04	0.10	0.16	−0.03	0.07	−0.32	—													
21	Mat. education	t1	0.08	0.09	0.14	0.13	0.20	0.21	0.01	0.13	0.17	0.11	0.20	0.21	−0.03	0.04	−0.02	−0.18	0.01	0.00	0.09	−0.16	—												
22	Closeness	t1	0.22	0.15	0.15	0.20	0.18	0.15	0.23	0.18	0.18	0.23	0.18	0.19	0.07	0.06	0.04	−0.09	0.07	0.04	−0.10	−0.03	0.08	—											
23	Closeness	t2	0.14	0.24	0.25	0.10	0.23	0.25	0.19	0.25	0.27	0.15	0.30	0.28	0.03	0.05	0.07	−0.08	0.10	0.02	−0.06	−0.08	0.15	0.67	—										
24	Closeness	t3	0.07	0.15	0.33	0.03	0.17	0.30	0.17	0.25	0.31	0.13	0.19	0.32	0.03	−0.01	0.06	−0.08	0.10	0.10	−0.08	−0.04	0.06	0.55	0.66	—									
25	Conflict	t1	−0.15	−0.03	−0.11	−0.10	−0.06	−0.12	−0.28	−0.25	−0.27	−0.07	−0.03	−0.05	0.03	0.04	0.02	−0.09	−0.01	0.09	0.04	−0.08	−0.03	−0.34	−0.29	−0.25	—								
26	Conflict	t2	−0.13	−0.04	−0.15	−0.04	−0.03	−0.08	−0.29	−0.35	−0.34	−0.08	−0.02	−0.03	0.02	0.12	0.03	−0.10	0.01	0.03	0.07	−0.06	−0.07	−0.31	−0.35	−0.34	0.71	—							
27	Conflict	t3	−0.07	0.02	−0.19	−0.02	−0.04	−0.16	−0.20	−0.27	−0.33	−0.09	0.00	−0.06	−0.01	0.13	−0.01	−0.09	0.01	−0.04	0.05	−0.05	0.00	−0.26	−0.33	−0.43	0.61	0.73	—						
28	School attend.	t2	0.13	−0.09	−0.12	0.20	−0.19	−0.18	0.13	−0.01	−0.04	0.21	−0.11	−0.12	0.13	−0.10	−0.08	0.61	0.04	−0.01	−0.01	0.08	−0.10	−0.05	−0.08	−0.09	−0.04	−0.03	−0.02	—					
29	School attend.	t3	0.12	0.02	−0.07	0.16	−0.09	−0.18	0.17	0.03	−0.03	0.22	0.02	−0.15	0.08	0.02	−0.07	0.86	0.01	−0.03	0.04	0.18	−0.20	−0.10	−0.05	−0.05	−0.13	−0.10	−0.08	0.47	—				
	Mean		4.24	4.28	4.24	4.03	4.09	4.05	3.78	3.90	4.01	3.40	3.58	3.63	4.10	4.14	4.10	4.87	0.47	0.11	0.44	1.37	0.60	4.30	4.26	4.20	2.21	2.24	2.31	0.23	0.58				
	SD		0.42	0.45	0.47	0.56	0.60	0.64	0.65	0.64	0.63	0.67	0.65	0.59	0.62	0.66	0.64	1.39	0.50	0.31	0.50	0.67	0.49	0.49	0.55	0.56	0.67	0.71	0.75	0.42	0.50				

Significant correlations ($p < 0.05$) are marked in bold. No. 1–15 and 22–27 = latent scores. MJ, manifest joy; CS, cognitive spontaneity; SS, social spontaneity; SH, sense of humor; PS, physical spontaneity.

TABLE 6 Model fit of unconditional second-order linear growth curve models in the total sample and separately in three age groups.

Score	$\chi^2(df)$	p	CFI	RMSEA	SRMR
Total sample (2–6 years)					
MJ	29.41 (23)	0.167	0.996	0.018	0.036
CS	36.15 (23)	0.040	0.991	0.026	0.035
SS	39.19 (23)	0.019	0.993	0.029	0.049
SH	24.27 (23)	0.389	0.999	0.008	0.030
PS	30.83 (24)	0.159	0.997	0.018	0.041
TPS	211.43 (87)	0.000	0.966	0.041	0.056
Subsample (2–3 years)					
MJ	29.71 (23)	0.158	0.990	0.035	0.065
CS	32.41 (23)	0.092	0.977	0.041	0.060
SS	18.98 (23)	0.702	1.00	0.000	0.051
SH	26.52 (23)	0.277	0.995	0.025	0.060
PS	48.02 (24)	0.003	0.973	0.064	0.069
TPS	138.93 (87)	0.000	0.961	0.050	0.097
Subsample (4–5 years)					
MJ	34.76 (23)	0.055	0.979	0.037	0.054
CS	28.83 (23)	0.186	0.992	0.026	0.039
SS	17.23 (23)	0.700	1.00	0.000	0.046
SH	25.45 (23)	0.328	0.998	0.017	0.063
PS	34.26 (24)	0.080	0.991	0.034	0.059
TPS	143.11 (87)	0.000	0.963	0.042	0.072
Subsample (6 years)					
MJ	36.70 (23)	0.035	0.973	0.052	0.069
CS	23.77 (23)	0.417	0.998	0.012	0.047
SS	26.04 (23)	0.299	0.996	0.024	0.070
SH	34.76 (23)	0.055	0.978	0.048	0.055
PS	13.98 (24)	0.947	1.00	0.000	0.042
TPS	148.73 (87)	0.000	0.943	0.056	0.090

Total sample, $N = 839$, $N_{\text{Cluster}} = 85$; subsample 2–3 years, $N = 242$, $N_{\text{Cluster}} = 38$; subsample 4–5 years, $N = 373$, $N_{\text{Cluster}} = 79$; subsample 6 years, $N = 224$, $N_{\text{Cluster}} = 50$; $\chi^2_{\text{diff}}(df)$ = difference test; MJ, manifest joy; CS, cognitive spontaneity; SS, social spontaneity; SH, sense of humor; PS, physical spontaneity; TPS, total playfulness score.

dimensions and for the total playfulness score. This indicates that children whose mothers had an academic educational level were rated higher in these dimensions. No significant effects were identified for gender, birth order, or number of siblings.

Effects on the slopes

Significant slope effects were identified for children's age and maternal education. Age had a moderate negative effect on

the slope in cognitive spontaneity, social spontaneity, and sense of humor and in the total playfulness score. In other words, children's ages resulted in different developmental trajectories in playfulness. Older children showed less growth or change than younger children. Maternal education was found to have a small positive effect on the slope in the social spontaneity dimension. Children with mothers with an academic level of education showed a steeper increase in social spontaneity than children with less educated mothers. For the other covariates, no effects of meaningful magnitude were observed on the slopes.

Parent–child relationship quality

Effects of the time-varying parent–child relationship quality were included as regressions on the corresponding measurement time point. For closeness in parent–child relationships, small to medium significant positive effects were found in all five dimensions and the total playfulness score at all three measurement time points except physical spontaneity at T3. This indicates that children who experience more warmth and openness in their parent–child relationships were rated higher in their playfulness at all times. Conflicts in parent–child relationships were related to less social spontaneity at all three measurement time points but to more sense of humor and more physical spontaneity at T2. However, no meaningful effects were found for conflicts in parent–child relationships on the total playfulness score.

School attendance

Results for the effects of school attendance on children's playfulness at T2 and T3 are reported in Table 8. Attending primary school showed a small yet significant negative effect in almost all dimensions except social spontaneity and cognitive spontaneity at T3 and in the total score of children's playfulness at T2 and T3. These results suggest that starting school leads to lower ratings for playfulness in children.

Discussion

The aim of the present study was to examine developmental trajectories of children's playfulness over a two-year period in children aged 2 to 6 years. Specifically, we investigated patterns of stability and changes over time in children's playfulness in a large sample of over 800 children and the effects of individual and family characteristics and transition to primary school. We applied second-order linear growth curve models and considered children's playfulness as a multidimensional construct with a multi-informant approach using parent and teacher reports. The results indicate that children's playfulness changes differently over the course of childhood depending on children's age and to different degrees on the individual dimensions of playfulness. In particular, the social components of playfulness were found to change over time. This finding could mirror children's developmental processes in social skills and changes in their play and learning environments with increasing age. However, a close parent–child

TABLE 7 Estimates of unconditional second-order linear growth curve models for the intercept and slope of children’s playfulness differentiated by children’s age.

Total sample (2–6 years)						
	MJ	CS	SS	SH	PS	TPS
$M_{Intercept}$	4.25 (0.03)***	4.04 (0.04)***	3.78 (0.03)***	3.41 (0.04)***	4.11 (0.03)***	4.39 (0.02)***
M_{Slope}	0.00 (0.02)	0.01 (0.02)	0.12 (0.02)***	0.13 (0.02)***	0.01 (0.02)	0.01 (0.01)
$V_{Intercept}$	0.11 (0.03)***	0.18 (0.03)***	0.31 (0.04)***	0.31 (0.04)***	0.23 (0.03)***	0.09 (0.02)***
V_{Slope}	0.03 (0.01)*	0.06 (0.02)***	0.05 (0.02)***	0.07 (0.02)***	0.04 (0.02)*	0.02 (0.01)**
$r_{Intercept/Slope}$	-0.37*	-0.32**	-0.44***	-0.57***	-0.21	-0.32**
Subsample (2–3 years)						
	MJ	CS	SS	SH	PS	TPS
$M_{Intercept}$	4.16 (0.05)***	3.70 (0.07)***	3.52 (0.06)***	3.04 (0.07)***	3.99 (0.06)***	4.26 (0.04)***
M_{Slope}	0.08 (0.03)***	0.25 (0.03)***	0.27 (0.03)***	0.34 (0.04)***	0.06 (0.03)*	0.12 (0.02)***
$V_{Intercept}$	0.14 (0.05)**	0.27 (0.07)***	0.32 (0.07)***	0.39 (0.07)***	0.18 (0.07)**	0.12 (0.03)***
V_{Slope}	0.03 (0.02)	0.10 (0.04)*	0.05 (0.03)	0.10 (0.03)***	0.00 (0.03)	0.02 (0.01)*
$r_{Intercept/Slope}$	-0.38	-0.42*	-0.64***	-0.61***	0.01	-0.38 [†]
Subsample (4–5 years)						
	MJ	CS	SS	SH	PS	TPS
$M_{Intercept}$	4.27 (0.04)***	4.14 (0.05)***	3.88 (0.04)***	3.50 (0.05)***	4.13 (0.04)***	4.42 (0.03)***
M_{Slope}	0.01 (0.02)	0.00 (0.03)	0.06 (0.02)*	0.08 (0.03)**	0.04 (0.02)*	0.01 (0.02)
$V_{Intercept}$	0.14 (0.04)***	0.20 (0.05)***	0.21 (0.04)***	0.29 (0.08)***	0.31 (0.06)***	0.09 (0.03)***
V_{Slope}	0.03 (0.02)	0.03 (0.02)	0.04 (0.02)*	0.03 (0.03)	0.03 (0.03)	0.01 (0.01)
$r_{Intercept/Slope}$	-0.64***	-0.25	-0.18	-0.49**	-0.53***	-0.43*
Subsample (6 years)						
	MJ	CS	SS	SH	PS	TPS ^a
$M_{Intercept}$	4.29 (0.05)***	4.19 (0.06)***	3.88 (0.07)***	3.66 (0.06)***	4.18 (0.05)***	4.47 (0.03)***
M_{Slope}	-0.08 (0.03)**	-0.12 (0.03)***	0.06 (0.03)*	-0.03 (0.04)	-0.07 (0.03)*	-0.08 (0.02)***
$V_{Intercept}$	0.02 (0.04)	0.12 (0.05)**	0.37 (0.07)***	0.09 (0.06)	0.13 (0.05)*	0.02 (0.02)
V_{Slope}	0.02 (0.02)	0.05 (0.02)*	0.06 (0.03)*	0.01 (0.03)	0.08 (0.03)**	0.01 (0.01)
$r_{Intercept/Slope}$	0.71	-0.22	-0.46***	0.39	0.10	—

^aNegative covariance; M, mean (unstandard.); V, variance (unstandard.); r, correlation (standard.); MJ, manifest joy; CS, cognitive spontaneity; SS, social spontaneity; SH, sense of humor; PS, physical spontaneity; TPS, total playfulness score; [†]p ≤ 0.10, *p ≤ 0.05, **p ≤ 0.01, ***p ≤ 0.001.

relationship proved to be significant for children’s playfulness at all time points.

Stability vs. change

When analyzing change over time in children’s playfulness, heterogeneous patterns were found: whereas the two social facets of children’s playfulness, social spontaneity and sense of humor, increased on average over the 2 years in the two- to six-year-olds, no significant changes were found in the dimensions of manifest joy, cognitive spontaneity, or physical spontaneity. These dimensions proved to be relatively stable. Interestingly, stability was found in those components that are usually first associated with playful children: exuberance, engagement, cheerfulness, and enthusiasm in play, developing play ideas and being imaginative and curious, joy in movement, physical activity, and coordination in play (Lieberman, 1977; Barnett, 1991a,b). These facets seem to represent consistent patterns of behaviors in children and may be less strongly determined by

specific play contexts, such as how children express their joy in play.

In contrast, interactions and group experiences are more likely to characterize the more social dimensions of children’s playfulness, such as taking play initiatives, playing cooperatively, managing play situations with peers by sharing and responding to others’ play ideas, fooling around, making jokes, and telling funny stories. These social settings increase with age as the child’s social-cultural environment constantly expands, socio-emotional skills become more differentiated, and interest in peers intensifies (e.g., Nicolopoulou and Smith, 2022). The results can be embedded and interpreted in the development of children’s play and their development of social competencies. Social play usually begins between the ages of three and four and increases throughout childhood. This is also referred to as more mature associated and cooperative play and is related to children’s social skills (Parten, 1932). Further research should examine the relationships between children’s playfulness and their cognitive and socio-emotional development in a longitudinal perspective. For example, recent studies have demonstrated the predictive

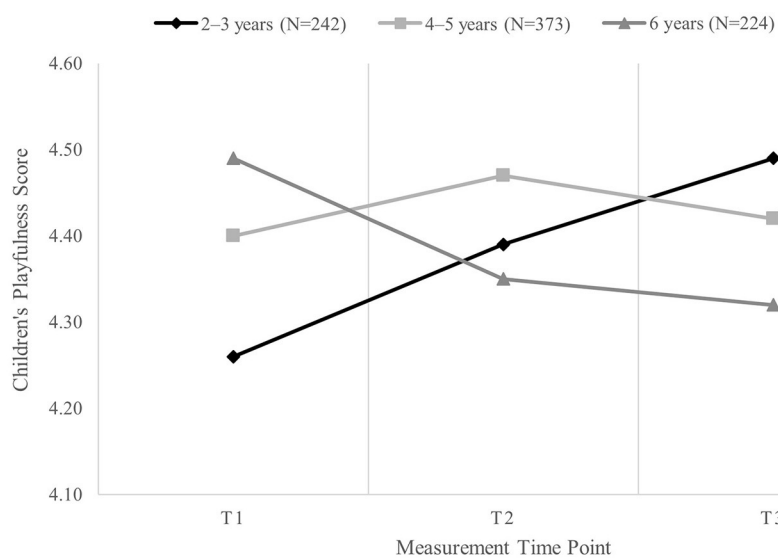


FIGURE 2

Representation of developmental trajectories in the total score of children's playfulness at three 1-year interval measurement time points (T1, T2, T3) differentiated by children's age at T1.

role of children's playfulness in their future social-emotional functioning (Fink et al., 2020; Fung and Chung, 2022) and that their playfulness depends on their cognitive growth (Waldman-Levi et al., 2022).

In the total score of children's playfulness, stability dominated in the average change over the 2 years in the two- to six-year-olds. However, the findings showed substantial interindividual variability in the growth curves: children differed in the extent to which their playfulness changed over time.

Age effects in developmental trajectories

Comparison of the three age groups showed that overall playfulness increased in children aged two and three over the 2 years, remained stable overall in children aged four and five, and decreased in children aged 6 years. For the youngest age group, the two- and three-year-olds, the findings are in line with the study by Waldman-Levi et al. (2022). There, an increase in children's playfulness was also observed between 6 and 24 months of age. The present study's group of four- and five-year-olds exhibited different patterns of stability and change between the three measurement time points: an increase from the first to the second time point (5–6 years), but a decline from the second to the third time point (6–7 years); between six and seven, changes occurred that led to this decline. One plausible explanation is the transition to primary school that is discussed later.

Nevertheless, children's age showed a significant positive effect on the initial starting point of children's playfulness. The older the children were, the higher the baseline score in all dimensions of children's playfulness. The findings are consistent with cross-sectional studies on positive age

effects in children's playfulness (Barnett, 1991a; Cornelli Sanderson, 2010; Bay, 2021; Ata and Macun, 2022) and align with the fact that children's play becomes more differentiated with age.

Gender effects

The present study also found heterogeneous patterns for gender in children's playfulness, in line with previous research: girls were rated higher than boys in the cognitive and social spontaneity dimensions but lower in physical spontaneity. However, boys and girls did not differ in their change over time. Furthermore, there were no gender effects on the total playfulness score. Neither gender proved to be generally more playful. The results are consistent with findings, for example, by Mabagala (2016), Keleş and Yurt (2017), and Mouratidou et al. (2023), but they did not confirm Cornelli Sanderson's (2010) findings that girls show higher global playfulness scores than boys. Nevertheless, investigating the significance of gender in the dimensions of children's playfulness provides information on how boys and girls differ in the manifestation and trajectories of their approach to play. This may support parents and professionals to develop a greater sensitivity for different play behaviors and the possible reasons for it (Barnett, 2018).

Sociodemographic effects

Migrant background was found to be significant for children's playfulness. Children who learn German as a second language were rated lower in their playfulness than children who speak the local language at home. To the best of our knowledge, there are hardly

TABLE 8 Conditional second-order linear growth curve models of children's playfulness depending on individual and family characteristics and school attendance.

		MJ		CS		SS		SH		PS		TPS	
		Intercept <i>b</i> (SE)	Slope <i>b</i> (SE)	Intercept <i>b</i> (SE)	Slope <i>b</i> (SE)	Intercept <i>b</i> (SE)	Slope <i>b</i> (SE)	Intercept <i>b</i> (SE)	Slope <i>b</i> (SE)	Intercept <i>b</i> (SE)	Slope <i>b</i> (SE)	Intercept <i>b</i> (SE)	Slope <i>b</i> (SE)
Time-invariant covariates (t1)													
Age		0.23 (0.07)	−0.21 (0.12) [†]	0.38 (0.07)	−0.52 (0.11)	0.35 (0.06)	−0.42 (0.11)	0.47 (0.06)	−0.51 (0.11)	0.12 (0.06) [†]	−0.09 (0.12)	0.42 (0.07)	−0.57 (0.12)
Gender ^a		0.01 (0.04)	−0.07 (0.07)	0.14 (0.05)	0.08 (0.07)	0.13 (0.04)	−0.02 (0.06)	−0.06 (0.04)	−0.05 (0.07)	−0.21 (0.05)	−0.10 (0.08)	0.02 (0.04)	−0.07 (0.08)
First born ^b		0.07 (0.07)	0.01 (0.09)	0.05 (0.07)	0.10 (0.08)	−0.13 (0.05)	0.10 (0.08)	−0.01 (0.05)	−0.01 (0.09)	0.05 (0.06)	−0.08 (0.10)	0.03 (0.07)	0.04 (0.09)
Number of siblings		−0.04 (0.07)	0.12 (0.09)	0.00 (0.08)	0.11 (0.07)	−0.13 (0.07)	0.13 (0.11)	0.03 (0.06)	−0.03 (0.10)	0.09 (0.07)	0.05 (0.08)	−0.01 (0.08)	0.10 (0.10)
Migrant background ^c		−0.19 (0.07)	0.03 (0.11)	−0.19 (0.07)	−0.01 (0.07)	0.00 (0.06)	0.02 (0.07)	−0.11 (0.06) [†]	0.00 (0.09)	−0.09 (0.07)	0.11 (0.09)	−0.22 (0.07)	0.03 (0.10)
Maternal education ^d		0.08 (0.07)	0.02 (0.10)	0.21 (0.06)	0.02 (0.07)	0.05 (0.06)	0.17 (0.08)	0.21 (0.05)	−0.02 (0.07)	0.03 (0.05)	−0.06 (0.09)	0.15 (0.06)	0.04 (0.09)
Time-varying covariates													
t1	Closeness	0.23 (0.05)		0.21 (0.04)		0.18 (0.04)		0.28 (0.04)		0.12 (0.04)		0.29 (0.04)	
	Conflict	−0.07 (0.06)		0.03 (0.06)		−0.16 (0.06)		0.07 (0.05)		0.07 (0.06)		0.00 (0.04)	
t2	Closeness	0.26 (0.05)		0.21 (0.05)		0.13 (0.04)		0.32 (0.04)		0.10 (0.05)		0.30 (0.04)	
	Conflict	0.06 (0.06)		0.01 (0.05)		−0.23 (0.05)		0.10 (0.05)		0.13 (0.06)		0.05 (0.06)	
	School attendance ^e	−0.10 (0.05)		−0.16 (0.04)		−0.05 (0.05)		−0.16 (0.05)		−0.13 (0.04)		−0.16 (0.04)	
t3	Closeness	0.30 (0.06)		0.25 (0.05)		0.16 (0.05)		0.35 (0.05)		0.07 (0.05)		0.35 (0.05)	
	Conflict	−0.08 (0.05)		−0.08 (0.05)		−0.24 (0.06)		0.10 (0.05) [†]		0.01 (0.05)		−0.04 (0.06)	
	School attendance ^e	−0.13 (0.06)		−0.09 (0.06)		0.01 (0.06)		−0.17 (0.07)		−0.15 (0.05)		−0.11 (0.06)	
<i>R</i> ²		0.10 (0.05)	0.06 (0.05)	0.23 (0.06)	0.27 (0.11)	0.14 (0.04)	0.22 (0.10)	0.25 (0.05)	0.27 (0.11)	0.08 (0.03)	0.05 (0.04)	0.24 (0.06)	0.33 (0.13)

N = 839. Significant results ($p \leq 0.05$) are marked in bold. [†] $p \leq 0.10$. *b* = growth parameter (standard.); SE = standard error; R^2 = variance (standard.); ^a1 = girls, 0 = boys; ^b1 = first born, 0 = second or later born; ^c1 = German as a second language at home, 0 = local language at home; ^d1 = academic degree, 0 = no academic degree; ^e1 = yes, 0 = no; MJ = manifest joy, CS = cognitive spontaneity, SS = social spontaneity, SH = sense of humor, PS = physical spontaneity, TPS = total playfulness score. Model fit: MJ, χ^2 (129) = 170.80, $p < 0.01$, CFI = 0.979, RSMEA = 0.020, SRMR = 0.027. CS, χ^2 (129) = 285.82, $p < 0.001$, CFI = 0.923, RSMEA = 0.038, SRMR = 0.035. SS, χ^2 (129) = 284.51, $p < 0.001$, CFI = 0.944, RSMEA = 0.038, SRMR = 0.045. SH, χ^2 (129) = 256.72, $p < 0.001$, CFI = 0.953, RSMEA = 0.034, SRMR = 0.034. PS, χ^2 (130) = 210.59, $p < 0.001$, CFI = 0.975, RSMEA = 0.027, SRMR = 0.033. TPS, χ^2 (277) = 727.94, $p < 0.001$, CFI = 0.901, RSMEA = 0.044, SRMR = 0.062.

any studies comparing playfulness across language backgrounds, so comparisons with other studies are barely possible. The only exception is a study by [Rentzou \(2013\)](#), in which no significant correlation was found. However, our finding could be interpreted as indicating that children with a migrant background are less socially integrated in various play contexts, feel less comfortable or safe, or are less able to express their emotions and ideas in play. In many cases, childcare center or kindergarten is the first contact with the local language for children of migrant background in Switzerland. Communication problems could initially make it difficult to actively engage in play with others. Different cultural beliefs and attitudes toward children's play (academic vs. play for its own sake) in the family environment could also be possible explanations for this (e.g., [Roopnarine, 2011](#)). The value of play, the selection of play partners, the context in which children's play takes place, as well as the time, content, and frequency of play are all affected by cultural beliefs and experiences (e.g., [Göncü et al., 2000](#)). Studies with refugee children have also shown that these children have a comparable play development, but less social interactions in their play (e.g., [Bernhardt et al., 2023](#)).

Our study found the number of siblings to have a negative effect on children's social spontaneity in play. This also applied to first-borns who were rated as less socially spontaneous in play than later-born children. The findings align with the studies by [Barnett \(1991a\)](#) and [Keleş and Yurt \(2017\)](#). Older siblings may provide a good early learning environment in which to gain social experiences essential to play. A larger number of siblings in turn may increase the potential for conflicts in play, for instance when sharing play materials, negotiating play ideas, and cooperating in play. Further analyses could build on this and also consider the play support or play participation of parents and professionals. It would be vital to raise awareness of the fact that children may need different levels of play support depending on whether they are an only child in the family or a child with siblings (e.g., acting more as a co-player or moderator or initiating play with peers).

In contrast to the study by [Bay \(2021\)](#), we found effects of maternal education on children's playfulness. Our study assessed maternal education as a key indicator of the socioeconomic status of the child's family environment. An academic level of maternal education was associated with higher overall playfulness in children, and particularly with higher levels of cognitive spontaneity and sense of humor in play. Additionally, we found a positive slope effect on the growth in social spontaneity: a steeper increase in children whose mothers had an academic educational level. These results agree with those published by [Barnett and Kleiber \(1984\)](#) and [Ata and Macun \(2022\)](#), which show that children with higher socioeconomic family backgrounds were reported as more playful. There are various possible reasons for this. One could be that mothers with an academic degree may value their children's play more highly and place more value on creativity and social interactions in their children's play and therefore provide more diverse play and learning environments for their children. However, further research is needed to identify potential patterns, for example in relation to the play support given by mothers and fathers.

Effects of close parent–child relationships

As hypothesized, children's playfulness was positively associated with closeness in parent–child relationships. These results are in line with the study by [Wu et al. \(2024\)](#). However, different patterns were observed for the conflict scale in parent–child relationships. Although more conflicts were associated with less social spontaneity, they were linked to a greater sense of humor and more physical spontaneity in children's play. These findings could be interpreted as coping mechanisms, for example by showing teasing and active facets in play and distracting themselves. Studies have shown that playfulness is positively related to effective coping in preschool children ([Saunders et al., 1999](#); [Ruckser-Scherb, 2010](#)). Nonetheless, conflict in parent–child relationships had no significant effect on the total playfulness score. The results highlight the significance of high-quality, warm, and supportive parent–child relationships for children's playful learning in early and middle childhood. Secure and intimate parent–child relationships provide the basis for children to explore the world around them in an excited, playful manner and to be socially engaged in and through play. Establishing close parent–child relationships is crucial for children to enter in social group play, use imagination and creativity in play, be able to express positive emotions in play, and generate appealing play ideas. As [Youell \(2008\)](#) noted, playfulness happens in relationships and stems from positive social experiences. There are also indications of parent-child similarity in the sense that more playful parents also tend to have more playful children (e.g., [Wustmann Seiler et al., 2021](#); [Wu et al., 2024](#)). Increasing evidence suggests that playful people seek out and mate with playful people (e.g., [Brauer et al., 2021](#)), and this may also be linked to the quality of the parent–child relationship, the role-modeling of parents, and the development of playfulness in children.

Attending school limits playfulness

Our results showed a negative effect of attending primary school at the second and third measurement time points. This negative effect may be related to children's adjustment to the formal school system's more structured environment, which demands self-discipline and self-control and reduces time for play in daily routines. It may equally result from children's generally greater developmental maturity at school age or to starting school as a stressful critical life event. Which of these changes or combination of changes cause the decline in playfulness observed cannot be clarified with the present data. Other studies have demonstrated a general decline in play with increasing age (e.g., [Mullan, 2019](#)). Further research is needed to identify whether entering school leads to more stress and thus a decrease in playfulness or whether the decrease in playfulness results from a shift to fewer playful activities and more formal learning in the classroom setting in middle childhood. [Barnett \(2018\)](#) noted that playful qualities such as spontaneity, exuberance, and physical activity seem to be incompatible with the more restrictive school setting, where rules and structure predominate and the demands on children to constrain their behavior increase. In her study, playful

behavior was perceived by teachers as disruptive, irritating, or inappropriate at school age, especially in boys, and this observation highlights the fragility of playfulness when the environment is increasingly dominated by rules, adults, and structured learning content. The question also arises whether the Children's Playfulness Scale (CPS) is still suitable for children aged six and over or whether it needs to be adapted for school-aged children and their altered environment. For example, some items do not appear to be age-appropriate for older children due to other interests or more cognitive and social maturity (e.g., "The child uses unconventional objects in play" or "The child is willing to share playthings").

Strengths and limitations

The present results offer an important contribution to research into children's playfulness. To the best of our knowledge, this was the first study to investigate children's playfulness longitudinally with three measurement time points and a broad age range in the sample and was thus also able to map the transition to school age. In addition, the study monitored a very large sample of over 800 two- to six-year-old children in childcare centers and kindergartens, investigated longitudinal relationships with individual and family determinants for the first time, and used complex statistical methods to measure developmental trajectories.

Nevertheless, the study has limitations. First, the application of the CPS does not allow a fundamental discussion of whether children's playfulness should be regarded as a trait, state, or capacity. This would require situation-specific measurements of children's playfulness over time and situation-specific predictors or state-based stimuli. The present study was able to provide information on which dimensions have proven to change or remain stable over 2 years. Further research is needed to investigate the basis of children's playfulness. It remains a concern of research into children's playfulness to examine the distinction between the multidimensional structure of playfulness and its consequences in-depth on a theoretical and empirical level (e.g., Proyer, 2018). Second, not all items of the CPS were used in our analyses. All dimensions of children's playfulness were measured using only three indicators each: 15 items instead of 23. In addition, the second-order factor, total playfulness score, was modeled on the five manifest subscales; a genuine second-order analysis with only latent factors was not conducted to limit model complexity. Also, children's total playfulness score was already rated as very high, so there was not much room for growth. In future, consideration could be given to extending the response format of the CPS. Furthermore, environmental aspects are generally not included in the CPS, and these could be considered in further scale adaptations (Cornelli Sanderson, 2010; Rentzou, 2013). Third, we were only able to examine linear growth curves as only three measurements of children's playfulness were available. Including more measurements would allow a more differentiated analysis of the form of change (e.g., linear vs. quadratic, cubic). Fourth, because of the study design, all participating children were recruited via childcare centers or kindergartens. These children may have more social play experiences than children who do not attend childcare or kindergarten. Fifth, during the two-year

study period, many children transferred to new institutions: from childcare center to kindergarten and from kindergarten to primary school. As a result, some of the ratings of individual children were given by different teachers. In addition, the entry into school occurred some 6 months before the second and third measurement time point. To analyze the impact of starting school in more detail, several assessments could be conducted directly during the transition to school. And finally, the variance in children's playfulness indicated that additional predictors should be included in further longitudinal analyses, such as aspects of children's socio-emotional and cognitive skills and mental health, aspects of the play and learning environment in childcare centers, kindergartens, schools, and families, and more detailed characteristics of parental play support. This could provide additional insight into the interplay between individual, family, and extrafamilial experiences.

Conclusion and implications

For the first time, longitudinal findings are available on developmental trajectories in children's playfulness aged 2–6 years over a two-year period. The results showed that the dimensions of children's playfulness differ in their development and determinants. In particular, the social facets of children's playfulness varied over time. In contrast, manifest joy and cognitive and physical spontaneity were rather stable. The characteristic that most influenced differences and changes in children's playfulness was children's age. Playfulness increased in children in the early years but decreased in children from school age onwards. Starting school had a negative effect on children's playfulness. These results could be explained by the more restrictive school setting, in which playful behaviors are valued differently. In contrast, closeness in parent–child relationships was found to be beneficial for playfulness in children at all time points. These results underline the importance of supportive parent–child relationships for children's playful learning throughout childhood.

For research and practice, the question arises how playfulness can be maintained as a resource in children and how schools can switch to a more playful pedagogy in which playful qualities are valued more highly. Playfulness reflects an individual's approach to learning situations, tasks, and social interactions that are also relevant in later life and has been shown to have positive effects on wellbeing and health (Proyer, 2013). Playfulness reveals the intrinsic motivation, social experiences, and creative potential that are crucial for lifelong learning.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the Ethics Committee of the Faculty of Philosophy at the University of

Zurich, Switzerland. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

CW: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Writing – original draft. ID: Data curation, Investigation, Writing – review & editing. CR: Data curation, Investigation, Writing – review & editing. PL: Conceptualization, Funding acquisition, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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