Changes in perspective: parenting and well-being of adolescents in daily life

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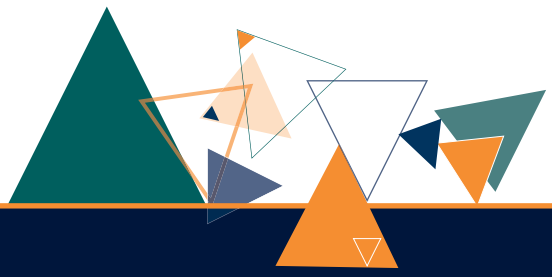
Tracking real-time proximity to assess parent-adolescent interactions in daily life



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Abstract

We present a novel method, using Bluetooth low energy beacons and a smartphone application, to examine frequency and duration of adolescents and parents time spent together in daily life by objectively tracking proximity in 77 Dutch families (77 adolescents (M_{age} = 15.9) and 145 parents (M_{age} = 48.9) for 14 consecutive days. Quality of parent-adolescent interactions was assessed using proximity triggered questionnaires. Overall, adolescents and mothers were more often in proximity and spent more time together than adolescents and fathers. Interactions and parenting behavior were generally rated as pleasant, but large differences between families were found in frequency and duration. This innovative method seems a promising tool to generate a deeper understanding of social interactions in daily life.

Keywords: proximity, ecological momentary assessment, Bluetooth beacon, parent-adolescent interaction, daily life

Introduction

Humans are social beings with a basic need to connect. Interpersonal relationships and social connectedness are of fundamental importance for human development and physical and mental health throughout the lifespan (e.g., Umberson & Karas Montez, 2010). During adolescence, one of the most proximal and important relationships for development and well-being is the one between parents and children (Bronfenbrenner, 1979; Sameroff, 2000). Various methods have been used to examine this relationship and the interactions between parents and adolescents, such as questionnaires, observations in the lab, computer tasks, and fMRI tasks. Although family processes in daily life were already assessed thirty years ago (Larson & Richards, 1991), the common availability of smartphones nowadays enables researchers to assess these daily interactions in more detail by using ecological momentary assessment (EMA; Stone & Shiffman, 1994). In addition to subjective reports, that have substantially improved our understanding of the daily lives of families, information on objective behavioral patterns may generate important additional insights into the interactions between parents and adolescents in daily life. Especially when objective patterns can be related to the quality of interactions. Smartphone features that can be used to passively capture data on proximity to other persons, such as Bluetooth, are potentially perfect tools to achieve this.

In the current study, we aimed to use a novel method with Bluetooth low energy (BLE) beacons and a smartphone application to track proximity of adolescents and parents and assess the frequency and duration of being close to each other in the daily flow of life. In order to yield new insights into the *quantity* of the interactions (i.e., time spent together) and whether this is indicative of the *quality* of interactions (i.e., warm/loving vs cold/rejecting), we also explored how parents and adolescents experienced these interactions with proximity triggered questionnaires after having been close to each other.

Assessing Social Interactions

Research has studied the interactions between parents and adolescents and their relationship quite extensively and demonstrated its importance for adolescent development and well-being (e.g., Smetana & Rote, 2019; Weymouth et al., 2016). While most studies focus on either subjective retrospective reports using questionnaires or on coded interactions in the lab (i.e., coded behavior), EMA is increasingly used to assess adolescents' and/or parents' subjective experiences of the interactions in an ecologically valid way in daily life (Trull & Ebner-Priemer, 2009) with reduced recall bias (Schwarz, 2007). Although this has enhanced our understanding of the dynamic interactions between adolescents and parents (Keijsers et al., 2021), this method is not without limitations. For example, impactful interactions can be missed when random sampling schemes are used (i.e., questionnaires triggered randomly throughout the day), whereas instructing families to indicate themselves when they interacted (i.e., event-contingent sampling) may be prone to bias. Especially when interactions are heated or unpleasant, parents and adolescents may not think about or feel like reporting this. To overcome these limitations and investigate patterns of interpersonal contact more objectively, it has been suggested to passively assess 'objective' markers that characterize interactions such as the physical proximity of people (Gupte & Eliassi-Rad, 2012).

Bluetooth Proximity Tracking

Proximity between people can be detected by several passive sensors (WiFi, GPS, or Bluetooth) that are currently available on almost all smartphones. The use of Bluetooth seems most promising in providing ecologically valid data on face-to-face proximity as it can measure proximity of people with an accuracy of 0 to 5 meters even indoors, depending on settings of the device (Liu & Striegel, 2011). With accuracy ranging between 3 and 50 meters, GPS and WiFi are less specific. Recently, researchers in the field of social sciences have started to test different approaches of using Bluetooth as a method to track proximity and assess social networks or dyadic proximity. Broadly three different methodological approaches can be distinguished. A first approach is detecting proximity between persons by only using (wearable) Bluetooth devices such as ActiGraph accelerometers that can either send or receive a Bluetooth signal. Studies showed that this approach is valid and reliable in a controlled and real-life setting both indoor and outdoor (Dlugonski et al., 2019; Kuzik & Carson, 2018). In a second approach, participants are provided with a research smartphone that detects proximity of others' phones or BLE beacons. Research showed that detecting proximity between dyads or larger networks with this approach is also promising and feasible (Maharjan et al., 2021; Van Woudenberg et al., 2020). The third approach involves installing an application on participants' own smartphones. One previous study piloted and tested an intervention for expressing gratitude, using proximity to other persons (i.e., social proximity) to trigger notifications (Ghandeharioun et al., 2016), and another study showed that proximity registered by badges was more related to self-report than registered by a designed smartphone app (Boonstra et al., 2017).

These studies have shown that proximity between persons can be tracked using smartphone Bluetooth with or without BLE beacons. The majority of studies, however, included small sample sizes (ranging between two devices and 40 participants) and the few studies that included larger samples in real life settings used a research smartphone (e.g., Stopczynski & Lehmann, 2018; Stopczynski et al., 2014; Van Woudenberg et al., 2020). While this has certain advantages (e.g., similar phone type and up-to-date software), it may also be burdensome for participants to carry two smartphones throughout the day. Moreover, when only using Bluetooth of the smartphone, combining different smartphone operating systems (i.e., iOS and Android) can be complicated. Hence, using a combination of BLE beacons with a smartphone application seems to be most reliable and feasible. The current study therefore aimed to explore a novel method to assess patterns of proximity between adolescents and parents (i.e., frequency and duration) in their daily life by using BLE beacons combined with an application installed on their own smartphone.

Proximity Triggered Questionnaires

Even though *quantitative* features of social interactions in daily life (e.g., being alone vs with people, being with friends vs partner) are important and have been found to relate to positive and negative affect in daily life, *qualitative* aspects (e.g., pleasantness of interaction, perceived support, or criticism) are more strongly linked to well-being in daily life (Liu et al., 2019). Thus, to advance the understanding of interactions between parents and adolescents in daily life and the impact on their well-being, we combined quantitative information of time spent together with assessments of how parents and adolescents perceived the quality of interactions and each other's behavior. The current study explored the value of using proximity triggered questionnaires to further improve our

understanding of the thoughts, feelings, and behaviors of both adolescents and their parents during an interaction. Moreover, we explored whether frequency and duration of proximity was indicative of the quality of interactions.

The Current Study

The current study aimed to enhance our understanding of parent-adolescent interactions in their natural daily life setting by: 1) exploring a novel method to assess frequency and duration of parent-adolescent physical proximity with BLE beacons; 2) examining how both parents and adolescents experienced the quality of interactions by using proximity triggered questionnaires, and 3) exploring whether the quantitative aspects of being in proximity (e.g., frequency and duration) are indicative of the quality of interactions. Since previous self-report studies reported that mothers spent more time with adolescents than fathers (Larson & Richards, 1991; Phares et al., 2009; Van Lissa & Keizer, 2020), we examined proximity between adolescents and their mothers and adolescents and their fathers separately. Given the innovative nature, no specific hypotheses were formulated and descriptions are provided on quantitative aspects of being in proximity (i.e., frequency and duration), experienced quality of parent-adolescent interactions (i.e., pleasantness, affect, and parenting behavior during interaction), and the associations between quantity and quality of interactions.

Methods

Sample

A subsample was used from RE-PAIR (Relations and Emotions in Parent Adolescent Interaction Research), a Dutch multi-method two-generation study examining the bidirectional interplay between parent-child interactions and adolescent mental well-being by comparing adolescents with a current major depressive disorder (MDD) or dysthymia and their parents to adolescents without psychopathology and their parents. The RE-PAIR study consisted of four parts: online questionnaires, a research day at the lab, two weeks of EMA, and a functional magnetic resonance imaging (MRI)-scan session with the adolescent and one parent. The subsample in the current study included families with an adolescent without psychopathology and focused on the EMA part of RE-PAIR.

Inclusion

Families were included in the study in case the adolescent and at least one of the primary caregivers wanted to participate in the study and had a good command of the Dutch language. Further inclusion criteria for adolescents were: being aged between 11 and 17 years, living at home with at least one primary caregiver, and having started secondary school. Families were excluded if adolescents had a current mental disorder, a history of MDD or dysthymia, or a history of psychopathology in the last two years. Adolescent psychopathology was assessed at the research day during a face-to-face Semi-Structured Interview, the Kiddie-Schedule for Affective Disorders and Schizophrenia – Present and Lifetime Version (K-SADS-PL; Reichart et al., 2000). Adoptive, foster, and stepparents (n = 14) were allowed to participate if they were involved in the upbringing of the adolescent for at least five years and if adolescents perceived the parent as a primary caregiver. For reasons of clarity, they will be referred to as mothers and fathers from here onwards.

For a detailed description of the recruitment procedure see (Janssen, Verkuil et al., 2021). Adolescents and their parents provided written active informed consent on the research day. For adolescents younger than 16 years of age, both parents with legal custody signed informed consent for participation of the adolescent. The final sample of RE-PAIR consisted of 80 families with a total of 233 participants (80 adolescents, 153 parents). Two fathers (1.3% of parents) did not participate in the EMA part of RE-PAIR due to too much time investment, resulting in a final sample for the EMA of 231 participants (80 adolescents, 151 parents). Since the BLE beacon cards did not work in three families (3.8% of families), the final sample for the current study consisted of 77 families (77 adolescents, 145 parents). For detailed information on the data cleaning process and missing data see Appendix 1. Sample demographics are presented in Table 1. The majority of adolescents (97.4%) and parents (94.5%) were born in the Netherlands.

Procedure

Adolescents and parents received face-to-face instructions during the research day about the EMA procedure, proximity tracking, and proximity triggered questionnaires. Next, researchers assisted participants with installing the Ethica Data application on their smartphones for the EMA and each family member received a personal BLE beacon for proximity tracking. Each family member also received written instructions and their individual account information of the Ethica app. Participants were instructed to keep the BLE beacon (in the size of a credit card) in their own phone case throughout the EMA period (14 consecutive days) or in the sticky card holder case provided by the researchers. Participants were additionally asked to carry their smartphone with them as much as possible, also inside their homes. A power bank was offered to participants if the battery life of their phones was impaired. Generally, the EMA started the next Monday after the research day, however in case of holidays and exam weeks of adolescents EMA started the first Monday thereafter. In addition to proximity tracking and proximity triggered questionnaires, participants received four EMA questionnaires a day (see Janssen, Verkuil et al., 2021 for detailed information).

Proximity

The Kontakt BLE Card Tags CT16-2 (i.e., BLE beacons) were used to track proximity (see Appendix 2 for detailed specifications and settings). The Ethica app scanned for BLE beacons in proximity. Due to smartphone manufacturer constraints scanning took place approximately every 5 minutes. Proximity data was logged by the Ethica app when at least one family member was carrying one's smartphone (with the Ethica app installed on it) and another family member was carrying one's BLE beacon and were close to each other within the specified range. We specified a maximum of approximately 4 meters distance within the same room. Each smartphone scanned independently for BLE beacons. In order to scan for BLE beacons, the Ethica app had to be active (in the background), had to have permission to access location services, and Bluetooth had to be turned on. Turning off the smartphone, retracting permission to access location services, switching Bluetooth off, manually terminating the Ethica app, using battery saving modus, and using night or flight mode blocked the scanning process.

Table 1. Sample demographics

Variables	*N*	
Adolescents		
Gender, % Female, (*n)*	77	64.9 (50)
Age (years), *M (SD)*[a]	77	15.9 (1.38)
Highest level of education, % (*n*)	77	
Vocational education		13.0 (10)
Advanced secondary education		33.8 (26)
Pre-university education		44.2 (34)
Secondary vocational education		6.5 (5)
Higher professional education		2.6 (2)
Living situation	77	
With biological mother		6.5 (5)
With biological mother and father		77.9 (60)
Other[b]		15.6 (12)
Daily positive affect[c], *M (SD)*	77	5.47 (0.76)
Daily negative affect[c], *M (SD)*	77	1.51 (0.63)
Parental warmth – mother[c], *M (SD)*	76	5.88 (0.81)
Parental warmth – father[c], *M (SD)*	69	5.76 (0.99)
Parental criticism – mother[c], *M (SD)*	76	2.03 (1.00)
Parental criticism – father[c], *M (SD)*	69	1.86 (0.92)
Parents		
Gender, % Female, (*n)*	145	52.4 (76)
Age (years), *M (SD)*[a]	145	48.9 (5.93)
Highest level of education, % (*n*)	145	
No diploma		0.7 (1)
Lower vocational education		7.6 (11)
Intermediate vocational education		26.2 (38)
Higher vocational education or scientific education (university)		65.5 (95)
Parental warmth – mother[c], *M (SD)*	76	5.68 (0.69)
Parental warmth – father[c], *M (SD)*	76	5.38 (0.73)
Parental criticism – mother[c], *M (SD)*	69	2.45 (0.95)
Parental criticism – father[c], *M (SD)*	69	2.47 (0.91)

[a]Age at research day

[b]Other options were parent and stepparent, alternating between father and mother, or living with adoptive/foster parents

[c]Person mean

Proximity triggered questionnaires

Participants received questionnaires based on proximity tracking as described above. If adolescents and parents departed from each other, after being in proximity for at least 10 minutes, a proximity questionnaire was triggered 10 minutes after departure. Adolescents received separate questionnaires regarding interactions with mothers and fathers and could thus receive two questionnaires after being in proximity of both mother and father. At first, the questionnaires expired after 10 minutes, but this was changed to 30 minutes after participation of three families. If a proximity questionnaire was triggered, it was blocked for the next 4 hours to limit the potential

number of questionnaires. See Figure 1 for graphical presentation of the proximity tracking process to trigger questionnaires.

Researchers monitored proximity tracking and proximity triggered questionnaires by actively checking real-time data in Ethica on a daily basis and were available for questions or problems via WhatsApp, telephone, and mail. If problems arose with proximity tracking or participants reported not receiving proximity triggered questionnaires, researchers inspected available proximity data and logs via the Ethica dashboard. Participants were asked to check and possibly change settings. On the last day of the EMA, a message was sent to thank participants and remind them of the scheduled phone call after the EMA to evaluate the EMA and to remind them to send the BLE beacons back to the researchers. The EMA of RE-PAIR, including adolescents without psychopathology and their parents, was conducted in the period between September 2018 and November 2019. As compensation for EMA, parents received €20,- and adolescents €10,-.

Measures

Frequency proximity

The frequency of physical proximity between adolescents and parents during the day was calculated per dyad by counting the number of occurrences that either the Ethica app on the adolescent's smartphone detected their parent's BLE beacon or parent's smartphone detected their adolescent's BLE beacon. If the smartphones of both the adolescent and parent detected each other's BLE beacon around the same time (within a time interval of 2.5 minutes), it was counted as one occurrence. Rationale for the specified time interval of detecting each other's BLE beacon is provided in Appendix 3.

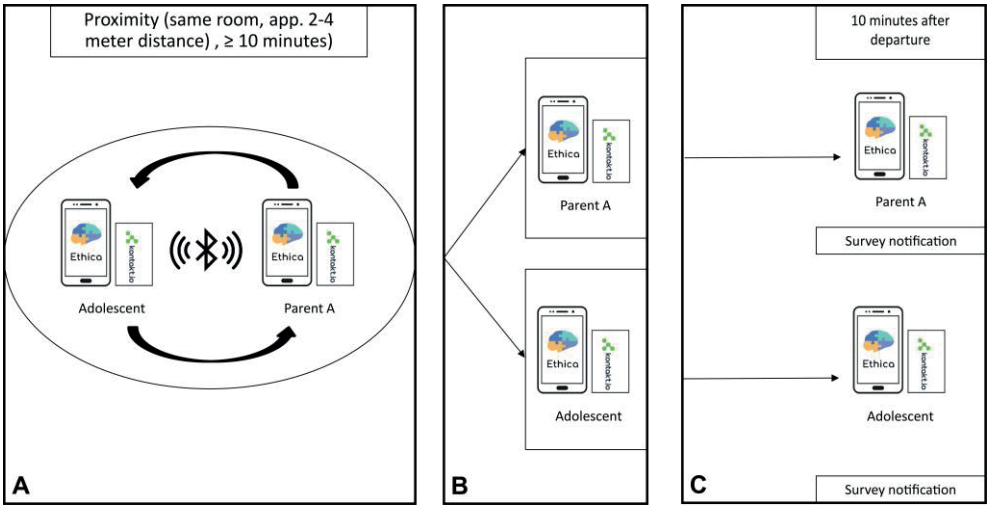

Figure 1. Graphical representation of proximity triggered questionnaires. Panel A shows proximity tracking with an adolescent and one parent (with their phones and BLE beacons) being in the same room in proximity (i.e., within a range of approximately 2 to 4 meters distance). Adolescent and parent depart from each other (Panel B). If the adolescent and parent were in proximity for at least 10 minutes, they received a proximity triggered questionnaire in Ethica 10 minutes after departure (Panel C).

Duration time spent together

Time spent together during the day (in minutes) was calculated when proximity was detected in two (or more) consecutive scanning intervals. Time intervals between the scans were summed when: i) the adolescent was in proximity of the parent for two or more scans, ii) the parent was in proximity of the adolescent for two or more scans, and iii) when adolescent and parent were in proximity of each other around the same time (within a time interval of 2.5 minutes) for two or more scans. Since scanning behavior is impacted by the smartphone and can be irregular, a cut-off of a maximum of 7 minutes per scan was used (see Appendix 4 for rationale for this cut-off).

Pleasantness of interaction

If a proximity questionnaire was triggered, adolescents and parents first indicated whether they actually had spoken to each other. If this was not the case, no follow-up questions were asked. If they did spoke to each other, they received follow-up questions about the interaction (i.e., pleasantness of interaction, affect, and parenting behavior). Adolescents and parents indicated the pleasantness of the interaction by answering the question "How was this contact?" on a 7-point Likert type scale with answer categories ranging from 1 (*very annoying*) to 7 (*very nice*).

Affect

Adolescents and parents rated their own affect states during the interaction with an adapted and shortened five-item version of the Positive and Negative Affect Schedule for Children (PANAS-C; Ebesutani et al., 2012; Watson et al., 1988). Two positive affect states (happy and relaxed) and three negative affect states (sad, irritated, and guilty) were assessed by asking "How did you feel during this contact?" followed by: "Happy", "Relaxed", "Sad", "Irritated", and "Guilty". Answers were given on a 7-point Likert type scale with answer categories ranging from 1 (*not at all*) to 7 (*very*). To create a score for positive affect per interaction, an average score of happy and relaxed was calculated for adolescents and parents separately. To create a score for negative affect per interaction, an average score of sad, irritated, and guilty was calculated for adolescents and parents separately.

Parenting

Adolescents rated parenting behavior of their parent during the interaction by answering the questions "How well did your mother/father listen to you?", "How well did your mother/father understand you?", "How critical was your mother/father towards you?", and "How dominant was your mother/father?". Answers were given on a 7-point Likert type scale with answer categories ranging from 1 (*not at all*) to 7 (*very*). Parents rated their own parenting behavior during the interaction by answering the questions "How well did you listen to your child", "How well did you understand your child?", "How critical were you towards your child?", and "How dominant were you towards your child?". Answers were given on a 7-point Likert type scale with answer categories ranging from 1 (*not at all*) to 7 (*very*). Two subscales were created, parental warmth and parental criticism. An average of listening and understanding behavior per interaction was calculated for adolescents and parents separately to assess parental warmth. An average of critical and dominant behavior per interaction was calculated for adolescents and parents separately to assess parental criticism.

Strategy for descriptive analyses

R version 4.0.1 (R Core Team, 2020) was used for the descriptive analyses. To explore the use of this novel method to assess parent-adolescent physical proximity with BLE beacons (aim 1), frequency of proximity between adolescents and mothers and between adolescents and fathers during the day was calculated by counting the occurrences of being in proximity throughout the 14 days, on average per day, and on average per week and weekend day. Duration of time spent together between adolescents and mothers and between adolescents and fathers during the day was calculated on average throughout the 14 days, on average per day, and the average duration of time spent together per moment. Normal distribution and equality of variances were checked and when assumptions were not met, appropriate nonparametric tests were used to examine differences between adolescent-mother and adolescent-father dyads in frequency and duration. To explore how parents and adolescents experienced the quality of interactions by using proximity triggered questionnaires (aim 2), we described adolescents' and parents' subjective experiences (i.e., affect and parenting) of parent-adolescent interactions. Lastly, to explore whether the frequency and duration measures were indicative of experienced pleasantness, parenting behavior, and adolescent affect (aim 3), Pearson correlations were used.

Results

Since some families reported that adolescents were not allowed to take their smartphones to their bedrooms during nighttime and smartphones were placed elsewhere, data collected during nighttime was removed from the dataset. The specification of nighttime was based on self-report EMA data of participants in RE-PAIR about bed- and risetime from the morning questionnaires of the standardized trigger schedule (see Appendix 5 for rationale). This resulted in using data collected from Monday until Friday between 7AM and 9.30PM as well as data collected on Saturday and Sunday between 9AM and 11PM, data outside this time interval was removed.

Description of parent-adolescent proximity

Frequency

Table 2 provides descriptive information on the average frequency of proximity between adolescents and parents throughout two weeks. To examine whether the frequency of being in proximity differed between adolescents and mothers and between adolescents and fathers, a paired Wilcoxon's signed rank test was used. Throughout the two weeks, adolescents were more often in proximity to mothers than to fathers (z = -5.079, p < .001). To gain more insight into the times during the day when adolescents and parents were together, the frequency of being in proximity was plotted throughout the days, see Figure 2. On weekdays, proximity between adolescents and parents started to increase from 1PM with a peak around 4PM, followed by a short decrease and then a peak again around 7PM or 8PM. A different pattern can be observed during the weekend when adolescents and parents seemed to be more often in each other's proximity throughout the day with a peak around 5PM on Saturday between adolescents and mothers and around 6PM between adolescents and fathers and around 7PM on Sunday. On average, proximity was detected 23 times per day between adolescents

and their mothers (*Min* = 1, *Max* = 199) and 16 times per day between adolescents and their fathers (*Min* = 1, *Max* = 177).

Duration of time spent together in proximity

Descriptive information on the duration of time spent together averaged over the two weeks between adolescents and parents is presented in Table 2. To examine whether the duration of time spent together throughout the two weeks differed between adolescents and mothers and between adolescents and fathers, a Paired Wilcoxon's signed rank test was used. Overall, adolescents spent more time together with mothers than fathers throughout the two weeks (z = -5.019, p < .001). On average, adolescents spent 74.83 minutes per day (*Min* = 4.17, *Max* = 653.23) together with their mothers and 51.02 minutes per day (*Min* = 4.93, *Max* = 563.62) with their fathers). When assessing weekdays and weekend days separately, adolescents spent on average 65.45 minutes per weekday (*Min* = 4.17, *Max* = 580.04) together with their mothers and 49.85 minutes per weekday (*Min* = 4.93, *Max* = 563.62) with their fathers. Regarding weekends, adolescents spent on average 93.91 minutes per weekend day (*Min* = 5.14, *Max* = 653.23) together with their mothers and 56.55 minutes per weekend day (*Min* = 5.19, *Max* = 542.69) with their fathers. To gain more insight into the average duration of a moment of spending time together, we calculated per individual how long each moment of spending time together lasted and provided the median. Overall, a moment of spending time together between adolescents and mothers lasted 19.63 minutes (*Min* = 2.08, *Max* = 320.59) and between adolescents and fathers 16.34 minutes (*Min* = 2.82, *Max* = 229.02). Results on frequency and duration time spent together based on one-sided and combined data are presented in Appendix 6.

Table 2. Descriptive statistics of the frequency and duration of adolescent-parent proximity during the two weeks

					Paired Wilcoxon's signed rank test	
	N	*Mdn*	Min	Max	*z*	*p*
Frequency						
Adolescent - mother	75	334	41	1108		
Adolescent - father	68	232.5	9	893	-5.079[a]	< .001
Duration (in minutes)						
Adolescent - mother	75	823	104.26	3715.36		
Adolescent - father	67	508.38	54.14	3677.11	-5.019[b]	< .001

Note. The median was reported since frequency and duration of proximity between adolescents and parents was non-normally distributed (all *p*'s < .001).

[a] n = 66

[b] n = 65.

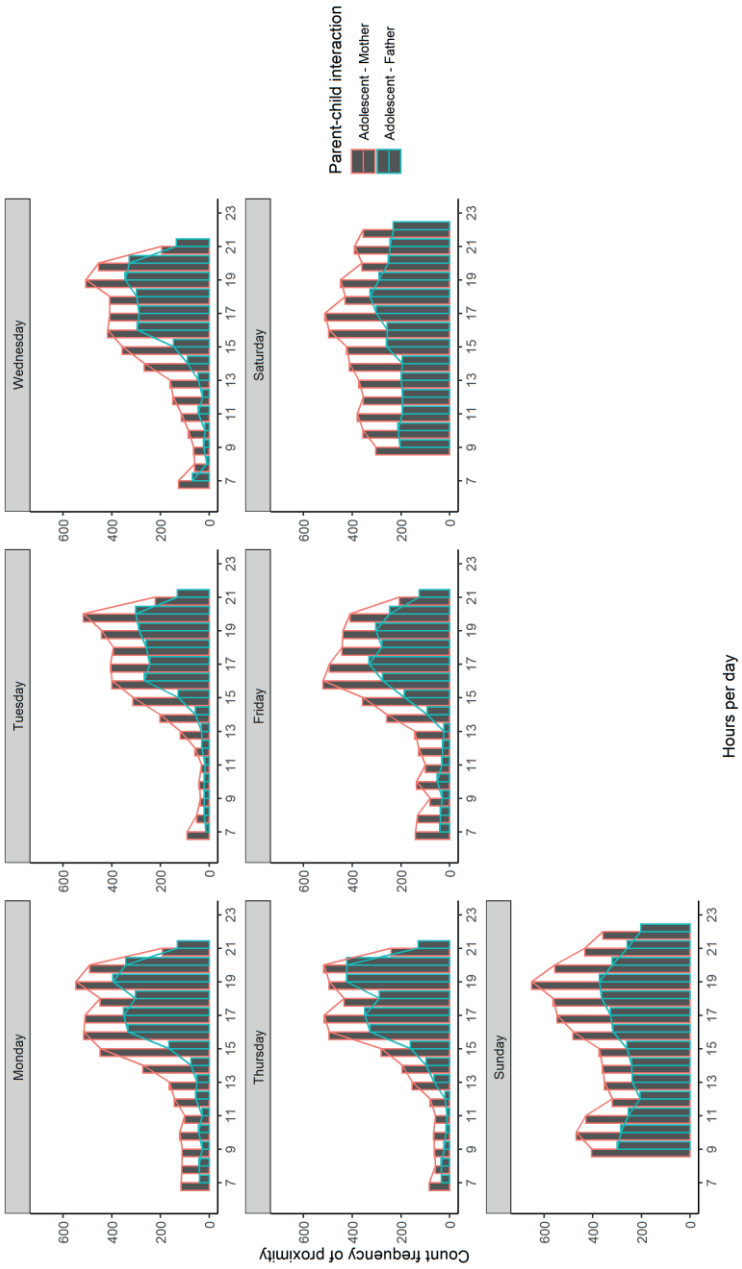

Figure 2. Frequency of proximity of adolescents and parents throughout days of the week per hour, separated for adolescent-mother and adolescent father dyads.

Description of experienced quality of interactions

A description of the number of proximity triggered questionnaires and compliance of these questionnaires are provided in Appendix 7. In 555 of the 844 answered questionnaires (65.8%) adolescents reported that they had an interaction with their parent. In 793 of the 986 answered questionnaires (80.4%) parents reported that they had an interaction with their adolescent. Detailed descriptive statistics of the subjective quality of the interactions between adolescents and their mothers and fathers are presented in Table 3. Overall, adolescents rated the interactions with their parents as rather pleasant, reported high on positive and low on negative affect, and were positive on parental warmth and reported low levels of criticism by both mothers and fathers. A similar pattern of results was found for parental reports.

To explore whether frequency and duration of proximity was indicative of the quality of interactions, we first calculated person-mean scores of the experienced quality. Next, frequency and duration of time spent together over the two weeks per dyad were calculated. Subsequently, Pearson correlation analyses were conducted to examine associations between quantity of proximity and quality of the interaction for adolescent-mother and adolescent-father dyads separately. Results are presented in Table 4. Frequency of proximity was not associated with adolescents' nor parents' affect, nor with the quality of parenting behavior. Duration of time spent together between adolescents and mothers did relate to parental criticism as reported by mothers, with more time spent together (between adolescents and mothers) being associated with less parental criticism (reported by mothers).

Results furthermore showed that in general adolescents who reported more positive and less negative affect also reported more parental warmth and less parental criticism of mothers and fathers. Interestingly, adolescents' positive and negative affect was also related to mothers' parenting behavior reported by mothers, with more positive affect and less negative affect being associated with more (mother self-reported) maternal warmth and less maternal criticism. Adolescent affect was not related to fathers' parenting behavior reported by fathers.

Table 3. Descriptive statistics of experienced quality of interactions for adolescents, mothers, and fathers

	N[a]	*Obs*	*M*	*SD*	Min	Max
Adolescent report						
Pleasantness interaction mother	49	319	5.66	1.10	1	7
Pleasantness interaction father	50	236	5.56	1.09	1	7
Positive affect interaction mother	49	319	5.65	1.11	1	7
Positive affect interaction father	50	236	5.70	1.05	1	7
Negative affect interaction mother	49	318	1.32	0.67	1	7
Negative affect interaction father	50	236	1.27	0.65	1	7
Parental warmth mother	49	318	5.88	1.09	1	7
Parental warmth father	50	236	5.80	1.21	1	7
Parental criticism mother	49	318	1.56	1.00	1	7
Parental criticism father	50	236	1.53	0.99	1	7
Parent report						
Pleasantness interaction mother	61	472	5.72	1.02	2	7
Pleasantness interaction father	54	319	5.59	1.03	2	7
Positive affect interaction mother	61	472	5.53	1.02	1	7
Positive affect interaction father	54	319	5.47	0.87	1.5	7
Negative affect interaction mother	61	472	1.31	0.69	1	5.33
Negative affect interaction father	54	319	1.32	0.62	1	4.67
Parental warmth mother	61	466	5.88	0.88	1	7
Parental warmth father	54	316	5.61	0.85	3	7
Parental criticism mother	61	466	1.94	1.30	1	7
Parental criticism father	54	315	2.11	1.27	1	6

Note. Obs = total number of observations

[a]Not all parents and adolescents received or completed proximity triggered questionnaires, therefore *N* is smaller than the sample size

Table 4. Correlations of experienced quality of interaction based on proximity triggered questionnaires and frequency of being in proximity and time spent together for adolescent-mother and adolescent-father dyads separately

	1	2	3	4	5	6	7	8	9	10
1. Frequency		0.936***	-0.084	0.128	-0.119	0.083	-0.139	-0.111	-0.127	-0.174
(*n*)		(67)	(50)	(50)	(50)	(50)	(54)	(54)	(54)	(54)
2. Duration time spent together	0.923***		-0.166	0.124	-0.064	0.046	-0.078	-0.114	-0.136	-0.179
(*n*)	(75)		(49)	(49)	(49)	(49)	(54)	(54)	(54)	(54)
3. Positive affect AA	-0.029	-0.100		-0.454***	0.746***	-0.371**	0.437**	-0.464**	0.157	-0.183
(*n*)	(49)	(49)		(50)	(50)	(50)	(41)	(41)	(41)	(41)
4. Negative affect AA	0.063	0.149	-0.671***		-0.525***	0.481***	-0.471**	0.342*	-0.265	0.070
(*n*)	(49)	(49)	(49)		(50)	(50)	(41)	(41)	(41)	(41)
5. Parental warmth AP	-0.027	-0.088	0.769***	-0.583***		-0.616***	0.515***	-0.454**	0.241	-0.058
(*n*)	(49)	(49)	(49)	(49)		(50)	(41)	(41)	(41)	(41)
6. Parental criticism AP	0.115	0.182	-0.505***	0.599***	-0.826***		-0.456**	0.384*	-0.375*	0.205
(*n*)	(49)	(49)	(49)	(49)	(49)		(41)	(41)	(41)	(41)
7. Positive affect PP	0.242	0.233	0.530***	-0.269	0.385*	-0.128		-0.487***	0.711***	-0.378**
(*n*)	(61)	(61)	(42)	(42)	(42)	(42)		(54)	(54)	(54)
8. Negative affect PP	-0.236	-0.214	-0.223	0.257	-0.191	0.142	-0.664***		-0.426**	0.492***
(*n*)	(61)	(61)	(42)	(42)	(42)	(42)	(61)		(54)	(54)
9. Parental warmth PP	0.110	0.129	0.485**	-0.367*	0.418**	-0.295	0.565***	-0.485***		-0.604****
(*n*)	(61)	(61)	(42)	(42)	(42)	(42)	(61)	(61)		(54)
10. Parental criticism PP	-0.245	-0.278*	-0.483**	0.340*	-0.366*	0.188	-0.509***	0.520***	-0.615***	
(*n*)	(61)	(61)	(42)	(42)	(42)	(42)	(61)	(61)	(61)	

Note. Correlations adolescent-mother dyads are presented under the diagonal, correlations adolescent-father dyads are presented above the diagonal.
AA = adolescent about self, AP = adolescent about parent, PP = parent about own behavior

Discussion

The common availability of smartphones and use of EMA have generated a new line of research focusing on adolescent and parent reports of well-being, parenting behavior, and interactions in daily life. In addition to subjective reports, information on objective patterns of parent-adolescent proximity obtained by smartphones features such as Bluetooth may provide important additional insights. In the current study, we therefore used a novel method to objectively assess the frequency and duration of parent-adolescent proximity with BLE beacons and a smartphone application. Additionally, we integrated this with questionnaires triggered by proximity to explore how parents and adolescents experienced interactions and whether quantity of interactions is indicative of the quality of interactions. Results showed that throughout the two weeks adolescents and mothers were more often in proximity and spent more time together than adolescents and fathers. Overall, both adolescents and parents generally rated the interactions and parenting behavior as positive. Findings also showed that when adolescents and mothers spent more time together, mothers reported less parental criticism during interactions. Our main finding is that this unobtrusive, innovative method is indeed able to objectively assess the quantity of parent-adolescent proximity in the daily flow of life. Moreover, the method enabled measuring subjective experiences of interactions based on proximity and relating these assessments to each other, which may have important implications for research and clinical practice.

Novel Method for Proximity Tracking

Researchers have proposed Bluetooth as a promising tool to provide ecologically valid data on proximity between persons indoors (Liu & Striegel, 2011) and previous studies broadly tested three different approaches of tracking proximity. Several factors however limited the broader and practical use of this method, such as burdening participants with a research phone or selective inclusion of participants with an Android smartphone. To overcome these limitations, the current study combined the use of BLE beacons with a smartphone application that could be installed on *any* smartphone which enabled gathering information on parent-adolescent proximity in daily life from both adolescents' and parents' smartphones. By using this innovative and unobtrusive method, the current study was able to objectively and continuously assess the frequency and duration of parent-adolescent proximity in daily life, which has not been assessed before.

Frequency and Duration

Our findings showed that adolescents and mothers were more often in proximity and spent more time together than adolescents and fathers which is in line with previous research (Larson & Richards, 1991; Phares et al., 2009; Van Lissa & Keizer, 2020) and validate these as we used an objective measure to assess proximity instead of using self-reports. Moreover, the current study and method gave a first glimpse into the specific patterns of parent-adolescent proximity throughout the week. On a weekday, proximity increased from 1PM onwards with a peak around 7PM and this pattern seems to resemble a typical school- and workday for families. At the weekend, proximity between adolescents and parents was more equally distributed and peaked on Saturday around 5PM and on

Sunday around 7PM. Interestingly, this peak on Sunday may be related to a typical Dutch habit of eating together while watching sports on television (weekly broadcasted at 7PM).

This novel method also provided an opportunity to calculate the duration of time adolescents and parents spent together. Although we may have slightly underestimated time spent together due to only including time of two or more consecutive scanning intervals, we found that adolescents and mothers spent on average approximately 75 minutes per day together and adolescents and fathers 51 minutes. This differed from a self-report study in which parents reported on time they spent in direct interaction (e.g., talking, playing a game) with their adolescent child. Mothers indicated to interact with their adolescents for almost 3.5 hours on an average weekday and almost 6 hours on an average weekend day. Fathers reported to interact with their adolescents on average for 2.5 hours per day during the week and 4.5 hours per day in the weekend (Phares et al., 2009). These different findings may in part be due to the age of the adolescents. In the current study, the mean age of adolescents was almost 16 years while in the self-report study this was 13.5 years. As adolescents get older, the time they spent with their families decreases substantially due to work and/or spending more time alone or with peers (Larson & Richards, 1991; Larson et al., 1996). Nevertheless, self-report bias may play a role here as well, since parents may overestimate the time they interact with their adolescent. Large discrepancies between objective and self-report measures have also been found in other areas of research, such as sedentary behavior (Chastin et al., 2018). Our objective measure of time spent together overcomes self-report bias and may therefore provide a more accurate reflection of the actual time spent together.

It should also be noted that we did find substantial variation between dyads in how often adolescents and parents were in proximity and the time they spent together which may represent actual differences between dyads. As mentioned above, variation in time spent together could be related to the age of the adolescent, as the age in this sample ranged from 11-18 years. Time spent together could, however, also be a valuable indicator of family cohesion (e.g., enmeshed, normal, disengaged) or quality of the relationship which may be highly interesting for future studies. For instance, a self-report study showed that adolescents who spent more time with parents perceived their parents to be more accepting (Desha et al., 2011). Moreover, in romantic partners it was found that more time spent together perceived by the women was related to a lower likelihood of divorce for women, while for men the opposite was found (Gager & Sanchez, 2003). This method may pave the way for future studies to further develop and validate the current method and yield novel insights into predictors and outcomes related to these objective measures of being close to each other.

Experienced Quality of Parent-Adolescent Interactions

By using proximity tracking to trigger questionnaires, the method enabled measuring adolescents' and parents' subjective experiences of their interactions in daily life shortly after they were in each other's proximity and exploring whether the quantity was indicative of the quality of interactions. Adolescents and parents sometimes indicated in these triggered questionnaires that they did not speak with one another (20% for parents, 35% for adolescents) which indicates that being in proximity does not have to imply that there was an actual interaction. Adolescents and parents could for instance be together, but each focused on an individual activity, or could be watching television together without actively speaking to each other (i.e., "interacting"). More in-depth investigation is necessary to further validate

the proximity triggered questionnaires. When adolescents and parents spoke to each other and rated their interactions, they indicated that overall it concerned rather pleasant interactions and they reported positively about their own affective states as well as parenting behavior. Previous studies also showed that Dutch adolescents and parents rated parenting behavior quite positively on a daily level (Janssen, Elzinga et al., 2021) and momentary level (Bülow et al., 2022).

We furthermore found that subjective experiences of parental criticism and warmth were related to adolescent positive and negative affect, but that frequency and duration were not related to adolescent affect experienced during an interaction. This differs partly from results of a previous EMA study that showed that both qualitative and quantitative aspects of social interactions were related to daily well-being (Liu et al., 2019). However, the different way of conceptualizing and assessing quantity as well as the type of social interaction (parent-child, intimate partner, friends) may play a role here. While we used passively captured data to objectively assess proximity between adolescents and parents, the previous self-report study assessed quantity of interactions by asking if participants were alone or with a friend. Another recent study that also objectively assessed quantity of social interactions by coding audio recorded snippets of 30 seconds every 10 minutes as interaction or not, did find a positive association between quantity of social interactions and well-being (Sun et al., 2020). In that study, however, social interactions were assessed every 10 minutes and included all social partners, while in our study proximity was continuously assessed and focused only on adolescents and parents.

Despite not finding an association between the objectively measured quantitative aspects of parent-adolescent interactions and adolescent well-being, quantity was related to some self-reported quality of interactions. When adolescents and mothers spent more time together throughout the two weeks, mothers reported less parental criticism during interactions. This seems to be in line with the findings based on self-report that greater involvement of parents in childcare activities (of children aged between 6 to 12 years old) were related to more desirable parenting behaviors (i.e., more warmth and consistency) (Sabattini & Leaper, 2004; Van Lissa & Keizer, 2020), at least for maternal criticism. While our finding is based on a small subsample (n = 61) and replication is necessary, it does provide a first insight into the interplay between objectively assessed quantity and experienced quality of parent-adolescent interactions in daily life.

Scientific and Clinical Implications

Although in in animal research tracking the frequency and duration of social behavior in the wild – by using proximity or other objective measures such as radio trackers – is rather common practice (e.g., Hunt et al., 2012) much less is known about this in our own species. Our method could provide a more objective, fine-grained, and ecologically valid assessment of being close to one another in general, not only of parent-adolescent dyads but also of other dyads (i.e., romantic partners) or larger groups (i.e., families, friends, peers, colleagues). Social science researchers may also use the method to examine the objective patterns of proximity in direct or indirect relation to for instance well-being. Some self-report studies have shown that more time spent together between adolescents and parents is related to better adolescent adaptation (Boele et al., 2020) and to fewer depressive symptoms through parental acceptance (Desha et al., 2011). Such associations based on self-report have not only been found in community samples, but also in clinical samples. Adolescents with a depressive disorder

seemed to spend less time with their families compared to healthy controls (Silk et al., 2011) and more time spent together was predictive of less depressive symptoms (Manczak et al., 2019).

Importantly, the method itself and the opportunity it provides to zoom in to the perceptions related to these social interactions could also be used as a diagnostic or intervention tool in clinical practice. Since proximity tracking happens in real-time it could help mapping the social network and interactions of a person in treatment. When relating this information to how this person reports to feel during or following these interactions and how behavior during interactions is perceived can be insightful for treatment such as system therapy or couples therapy. Thus, both aspects of our novel method (i.e., proximity tracking and proximity triggered surveys) have the potential to contribute to providing tailored feedback. Moreover, the proximity triggered questionnaires might also be useful for interventions. For instance, if parents are in proximity of their child and indicate that they think their child is feeling blue, a message could be sent on how to express empathic parenting.

Strengths, Limitations, and Future Directions

By using a novel method with BLE beacons and a smartphone application, the current study was able to objectively and ecologically valid assess frequency and duration of parent-adolescent proximity in daily life. By using an existing and easy to use application that can be installed on any smartphone, this method can easily be applied to assess daily social interactions between for instance friends or romantic partners. As a first validation of the method, we showed that tracking of proximity indicated that adolescents and mothers had more frequent and longer daily contact compared to adolescents and fathers. We furthermore successfully applied the technique of triggering questionnaires based on proximity between adolescents and parents, providing the opportunity to gain a better understanding of how both adolescents and parents experienced an interaction, without a bias of event-contingent sampling. Moreover, by combining these two features we managed to generate some first insights into the relation between objectively assessed quantity of being together and experienced quality of parent-adolescent interactions.

The development of a new method generally comes with several methodological and conceptual challenges that can guide future studies. Even though the use of Bluetooth has been shown to be most promising in providing ecologically valid data with great accuracy indoors (Liu & Striegel, 2011), other Bluetooth devices or WiFi can affect the accuracy of smartphones' BLE signal detection. Moreover, several types of BLE beacons are available that may differ in accuracy. More research is necessary on the differences between the BLE beacons and the impact of other signals on the accuracy. Furthermore, due to rapid technological development of applications and phones, software systems are updated regularly which can impact the scanning intervals or settings. Future research might want to control for this or ask participants explicitly to not update their phones. Additionally, our objective measures and the found variation between families may be impacted by factors such as using flight modus or turning off Bluetooth which blocked the scanning process. Participants were instructed to not change settings but not all adhered to these instructions at all times. Since the data logs did not provide information on all settings, we tried to reduce the impact of participants' behavior by combining information of proximity tracking by the smartphones of both adolescents and parents. We also reminded them of the correct settings when monitoring, but future studies could possibly use data donation methods (i.e., ask participants to share the logs of their

smartphone) to gain more exact insight into the use of these settings and correct for it. Lastly, although frequency and duration of adolescent parent-proximity were conceptually different, they were highly correlated in our study. It could therefore be argued that using one measure might be best and future studies could decide which measure to use based on their research question.

Conclusion

The use of EMA has enhanced our understanding of the parent-adolescent relationship and interactions in daily life based on self-report and obtaining objective information on behavioral patterns of proximity may generate important additional insights. By using a novel method with BLE beacons and a smartphone application, we were able to unobtrusively track proximity between adolescents and parents, calculate frequency and duration, and trigger questionnaires based on this proximity to assess quality of parent-adolescent interaction in daily life. Results showed that adolescents were more often in proximity and spent more time together with mothers than fathers. For mothers, the duration of interactions with their adolescent child was negatively related to parental criticism, with more time spent together being related to less parental criticism. In sum, this method seems a promising tool to quantify social behaviors that can be applied to enhance the understanding of social interactions in daily life and in clinical practice.

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