Interrupted Time Experience in Autism Spectrum Disorder – Empirical Evidence from Content Analysis

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Abstract

Although the experience of time is of central relevance for psychopathology, qualitative approaches to study the inner experience of time have been largely neglected in autism research. We present results from qualitative data acquired from 26 adults with high functioning autism spectrum disorder (ASD). Employing inductive content analysis we identified a distinct pattern of interrupted time experience in ASD. Individuals with ASD seemed to implement structured and routine behavior by future planning to guarantee that the present passed uninterrupted. We reason that the success of corresponding compensatory mechanisms determines the development of distress and noticeable symptoms. Considering recent theories on Bayesian perceptual inference we relate the syndrome of interrupted time experience to the putative neuronal mechanisms underlying time experience.

Keywords: autism spectrum disorder, time experience, perceptual inference, psychopathology, content analysis

1 Introduction

Human beings both act and interact in time. Emphasizing the temporal character of interaction, the experience of time has repeatedly been linked to *intersubjectivity* (Fuchs, 2001; Wyllie, 2005; Vogeley & Kupke, 2007; Botbol et al., 2013; Fuchs, 2013; Mölder, 2016; Nielsen, 2017), and psychopathological disturbances of time experience repeatedly have been associated with disturbances of intersubjectivity on a temporal level (Fuchs, 2005; Wyllie, 2005; Fuchs, 2013; Moskalewicz, 2015a; Moskalewicz, 2015b; Stanghellini et al. 2016; Fuchs & van Duppen, 2017; Nielsen, 2017). These observations and hypotheses suggest an intricate relationship between time experience and social behavior.

Autism spectrum disorder (ASD) is a psychopathological condition exhibiting “deficits in social communication and social interaction across multiple contexts“, and “restricted, repetitive patterns of behavior, interests, or activities“ (American Psychiatric Association 2013, p.50). Taking a closer look at the two primary symptom clusters of ASD, we observe on the one hand, deficits in social interaction and on the other hand, deficits in what may be classified as temporal behavior and structure either through repetition or insistence on sameness (Allman et al. 2011; Falter et al. 2012a; Gil et al. 2012). Non-surprisingly, ASD has received increasing interest from scientists and researchers interested in disturbances and alterations in time perception, time production and time experience.

Concerning these various aspects of human time, a multitude of results has repeatedly demonstrated atypicalities in ASD: disturbed neuronal timing (Brock et al., 2002; Welsh et al. 2005), impaired perception of time intervals (for review see Allman & Falter, 2015; Allman & Mack 2012; Falter & Noreika 2014), alterations of perceptual temporal resolution and sensory

integration windows (Bebko et al. 2006; Foss-Feig et al. 2010; Falter et al. 2012b; Gepner & Féron, 2009; Woynaroski, 2013; Noel et al., 2017), temporal acuity (Noel et al., 2018), abnormal neuronal processing of time experience (e.g., Lepistö et al. 2005, Lepistö et al. 2006; Rippon et al. 2007; Falter et al. 2013), an impairment in so-called *diachronic thought* (Boucher et al., 2007), anomalies in clock genes and circadian timing (Wimpory et al., 2002; Nicholas et al., 2007), and abnormal temporal synchrony of behavior in interactions (e.g. Trevarthen & Daniel, 2005). It has previously been argued that these anomalies may relate to the above mentioned primary symptoms of ASD (Boucher J, 2001; Gepner & Féron, 2009; Allman, 2011; Allman et al., 2011; Tordjman et al., 2015), however, as of yet definitive conclusions cannot be drawn.

It has recently been suggested, that temporal flow and hence time experience may be constituted by the continuous processes composing Bayesian perceptual inference (Hohwy et al. 2016; also see Vogel et al., 2018a). Bayesian inference states that top-down inferences regarding our environment, called priors, are constantly updated by the neural system depending on bottom-up perceptual information (e.g. Friston et al., 2014; Petzschner et al., 2017). The active prior reflects what the neural system presently considers important and which hence is registered as conscious experience. The priors are activated according to a hierarchy with lower priors reflecting fine-grained beliefs and higher priors reflecting coarse-grained, general beliefs. An inference is changed as soon as an active prior no longer provides the best explanation for an incoming perceptual input. In this case, a new, better fitting prior is selected. It has been speculated that the transfer from one prior to the next generates temporal flow (Hohwy et al. 2016). Furthermore, it has been speculated, that so-called hypo-priors (Pellicano & Burr 2012, Hohwy et al. 2016), i.e. priors which carry more perceptual detail and consider important a larger amount of perceptual input, are the underlying cause for symptoms in ASD (Hohwy et al. 2016). Hypo-priors lead to a more permeable perceptual filter and more detailed perceptual information (Hohwy et al. 2016). More detailed perceptual information in individuals with ASD will need more time to be processed as compared to the corresponding, less detailed perceptual input in persons without ASD (Pellicano & Burr 2012) and the implicit flow of neural information comparatively may lead to a decrease in the velocity of the integration of perceptual input (Hohwy et al. 2016). Consequently the speed at which the external world changes - especially with regards to other persons - will seem faster; the implicit flow of time will speed up (Gepner & Féron 2009; Hohwy et al. 2016).

Please note, that it is not the consciously experienced velocity of the passage of time that increases. In the case of Bayesian perceptual inference we describe implicit neural processes not accessible to conscious experience. However, these implicit processes are themselves liable to time, as it takes these processes a certain time to be completed (Varela, 1999; Vogeley & Kupke, 2007). It is these basic processes on a deeper and more fine-grained layer of time which are considered to take longer in ASD due to a higher perceptual density.

These considerations suggest a considerable significance of the implicit processes underlying time experience for ASD. Still, primary symptoms of ASD remain defined within a framework of inner experience and behavior. Yet, the focus of the aforementioned studies was either on individuals' behavior in time or their *judgments* of temporal aspects of stimuli sparing an important building block of experience and behavior, namely temporality, the very introspective experience of being in time and of time itself.

Hence, the aim of the current study is a comprehensive investigation of time experience in ASD by means of a qualitative research approach. As a mentionable exception to the so far merely quantitative research in the field, Zukauskas et al. (2009) phenomenologically analyzed qualitative data from interviews with 13 participants diagnosed with ASD and found that their participants demonstrated a "factual experience" (p.95) when referring to time: the present was described through specific and isolated facts, being a "prolongation" of the past (p.104); periods of time were described in reference to repetitive behavior and routine; the general concept of time relied on clocks and calendar dates, and it was dominated by the order of activities and the sequence of routines; the future was described in stereotypical terms and was devised of specific facts like isolated routines. The authors reported the "fullest sense of time" (p.103-104) for the experience of

the past and concluded, that individuals with ASD focus on facts without an extended temporal perspective. Focusing specifically on the sense of past, present, and future, the authors did not include the experience of the passage of time in their investigation. Nevertheless their findings denote a unique experience of time in ASD, related to symptomatology and possibly in accordance with neuropsychological findings and considerations.

The experience of time may pose a deep but distinct phenomenon to ASD. Notwithstanding the probable relationship between time experience, social interaction, and their disturbance in ASD, the link between them has not been investigated and adequate quantitative measures are not yet available. From a clinical and diagnostic standpoint this indicates further psychopathological investigation to foster better understanding of time experience in ASD and to prepare a potential diagnostic resource.

We present qualitative data on the experience of time obtained from participants with ASD. We compare our findings with those from a previous study employing the same methodological approach on healthy participants (Vogel et al., 2018a), in order to potentially identify and discuss distinct differences between individuals without ASD and without history of mental disease. This explorative approach holds the potential to not only provide additional understanding of the experience of adults with ASD, but also to generate novel hypotheses for further quantitative and experimental research.

2 Material and Methods

2.1 The Time Questionnaire

We employed the Time Questionnaire (TQ) (Figure 1), an open question questionnaire specifically designed for qualitative inquiry into the experience of time. .

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The TQ is based on a conceptual distinction within the conscious experience of time between the flow or passage of time and the structure of time (past, present, future). This distinction is by no means trivial, as it has previously been speculated that differentiating between the flow of time, and the structure of time, may be useful in order to differentiate psychopathological conditions (Kupke, 2007; Kupke & Vogeley, 2009; Fuchs, 2013; Fuchs & van Duppen, 2017; Stanghellini et al., 2017; Vogel et al., 2018a). Questions (Q) 1-3 address the experience of the passage of time. Q1 is phrased as open as possible, whereas Q2 further inquires into intersubjective and interactional variance and Q3 addresses situational changes in experience. Q4 through Q7 were designed to address the three temporal dimensions of time (past, present, and future) and related experience and concepts. Additional space was provided to participants to write anything they further deemed relevant.

Participants were instructed to write as much or as little as they found sufficient to answer each question. No time limits were given in order to guarantee data adequacy through proper data saturation (Sandelowski, M., 1995; Pope, C. et al. 2000; Mason, M., 2010; Glaser B., & Strauss A., 2017). The TQ has been successfully used in two recent studies (Vogel et al., 2018a; Vogel et al., 2018b) and been demonstrated to sufficiently address both passage and structure of time with differential diagnostic resolution.

2.*2 Participants*

Volunteers were recruited through the Autism Outpatient Clinic at the Department of Psychiatry, University Hospital Cologne, Germany. The Outpatient Clinic provides diagnostic services, self-help groups and cognitive-behavioral therapy based group therapy. For research purposes German native speakers between 18 and 65 may volunteer for study participation after confirmed diagnosis

via an e-mail distribution list. Before study inclusion all volunteers were clinically rescreened in a psychiatric diagnostic interview by the principal investigator qualified for establishing clinical diagnosis (KV). Participants were included if they met diagnostic criteria for Asperger Syndrome (acc. to ICD-10, World Health Organization, 1992), and if they had no record of comorbid neurological or comorbid psychiatric disease, including organic brain disease, mental retardation (IQ<70), bipolar disorder, psychosis, schizophrenia, anxiety disorders, major depressive disorder, and addiction. Participants were included if they were not taking any neuropsychiatric or any otherwise psychoactive or illegal drug over the period of investigation. Although the diagnostic interview was the primary criterion of inclusion we acquired psychometric data from all participants for additional information. Retrospective scores from the Autism-Spectrum Quotient (AQ), a 50-item questionnaire designed to assess autistic spectrum traits in the general population (Baron-Cohen et al., 2001) were available for n=17 included participants. Although its validity has not been sufficiently established for ASD (Cassidy et al., 2018), we administered the Beck-Depression-Inventory (BDI-II) (Hautzinger et al., 1995), a self-assessment multiple choice test to all participants in order to account for depressive symptoms potentially interfering with time experience (Thönes & Oberfeld, 2015; Vogel et al., 2018b). We administered a multiple choice vocabulary test for verbal intelligence (WST) (Schmidt & Metzler, 1992) to all participants in order to guarantee sufficient language proficiency and rule out potentially interfering speech development disorders. Participants were matched to the healthy population reported in Vogel et al. (2018a) according to verbal IQ in order to rule out any confounding influence from group differences in verbal communication. Demographics and results from AQ, BDI-II and WST are presented in Table 1.

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2.*3 Qualitative Analysis*

All returning documents were analyzed according to summarizing content analysis (SCA; Mayring, 2014) using inductive content analysis (Pope, C et al. 2000). This hypothesis-free approach was considered to be the most adequate due to the lack of sufficient prior investigation into qualitative time experience in adults with ASD. The aim of the explorative methodology was to generate a comprehensive data based description for future quantitative and experimental studies by giving a qualitative description as detailed as possible.

According to SCA, the material was screened for unnecessary examples, redundancies, and repetitions, which were deleted. The remaining text was, if necessary, paraphrased into understandable common language by correcting incorrect orthography or grammar. From the paraphrased material, single statements were identified. For the purpose of coding the whole material, descriptive, categories were formed for each single statement. Statements could range from a single word to a complete answer to a single question of the questionnaire. After all statements of one participant had been assigned to a category, the next participant was coded. After all participants had been coded in this way, the material was re-screened, and categories of similar or identical content were merged. This process was repeated until a reliable categorical system had been established. The material saturated at 26 participants, meaning that further inclusion had not yielded any additional information (Sandelowski, M., 1995; Pope, C. et al. 2000; Mason, M., 2010; Glaser B., & Strauss A., 2017).

To check the categorical system for reliability, two naïve inter-coders (K.K., T.S.) were provided with the paraphrased material and a descriptive table, consisting of an explication, a coding rule, and an anchor example for each of the established categories (Table 2). Each inter-coder then independently coded the material. From the original code and both inter-coder results we

calculated Krippendorff's alpha (Krippendorff, 2004; Hayes & Krippendorff, 2007) in order to evaluate inter-coder agreement.

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3 Results

We identified a total of 285 statements which were coded according to 36 categories. The categories were arranged in five groups. The first group referred to the passage of time (101 statements; categories K01-K15). The second group concerned the experience of the present (69 statements; categories K16-K23). The third group addressed the experience of the past (49 statements; categories K24-K30). The fourth group concerned the experience of the future (56 statements; K31-35). The last group was labelled *Rest* and contained a single category coding for all statements which did not fit any other provided category (8 statements; K36). The calculated inter-coder agreement of Krippendorff's alpha resulted in a strong agreement of α=0.86.

3.1 Categories within the Group concerning the Passage of Time

Among the 101 statements within 15 categories addressing the experience of the passage or flow of time, one category (category K15; n=6, 23% of participants) described the experience of time as generally flowing and passing. Several categories (K06-K08, K14; in total 22 statements) referred to general changes or alterations in the passage of time unrelated to situational variance including a generally imprecise sense of time (category K07; n=10, 38% of participants) and the necessity of a clock to experience the passage of time (category K08; n=3, 12% of participants). Time was experienced as passing generally fast (category K14; n=4, 15% of participants) or passing with variable velocities, without mentioning any influential factors (category K06; n=5, 19% of participants).

Seven categories (categories K01-K04, K09, K13; in total 56 statements) contained statements reporting changes in the experience of time in relation to situational changes: the passage of time sped up during pleasant activities (category K01; n=10, 38% of participants) or during engaging and interesting activities (category K02; n=9, 35% of participants); the experience of the passage of time appeared to fade or disappear during engaging activities (category K03; n=6, 23% of participants) or to slow down during unpleasant situations (category K04; n=14, 54% of participants). Structured and routine behavior also substantially influenced the passage of time (category K13; n=12, 46% of participants), resulting either in a pleasant effect on the experience of time (n=3), in a "normalized" experience of time (n=3) or decreasing an otherwise unpleasant experience of time (n=3), stress or surprise (n=4). Structure and routine behavior could also result in changed velocity of passing time, either as slowing down (n=3) or speeding up (n=1). The passage of time was experienced as going faster with age (category K09; n=5, 19% of participants).

Four categories (category K05, K10-K12; in total 30 statements) referred to changes in the experience of the flow of time during social situations. Although the influence of social encounters on time experience was denied by 7 participants (category K05; n=7, 27% of participants), passage of time was also experienced to change in social contexts, either with decreasing (category K10; n=7, 27% of participants) or increasing velocity of the passage of time (category K11; n=5, 19% of participants). Four individuals (category K12; n=4, 15% of participants) even stated that during social interaction the passage of time was not registered or felt.

3.2 Categories within the Group concerning the Present

At a first superordinate level, categories addressing the present could be assigned to two diverging attitudes. The present was either experienced as a "snapshot" in the sense of a time point (categories K16, K19, K20; in total 25 statements) or as an extended duration (categories K17, K18, K21, K23; in total 36 statements). The categories relating to snapshot perceptions described the present as a point in time or as lacking duration (category K16; n=8, 31% of participants), as a current, momentary instant (category K19, n=11, 42% of participants) which cannot be consciously experienced and which is not real (category K20, n=8, 31% of participants). The seemingly deviating experience of the present as an extended period of time (category K17, n=11, 42% of participants), related to the present as being identifiable with a currently performed activity of varying duration (category K18, n=9, 35% of participants) which meant refuge and sanctuary from external events (category K21, n=4, 15% of participants) and had to be utilized and spent in a meaningful manner (category K23; n=10, 38% of participants).

On a different note, two participants (category K22; n=2, 8% of participants) deemed time as generally unimportant. One of these participants experienced time in general as unimportant, and the other referred to the past, present, and future as meaningless.

3.3 Categories within the Group concerning the Past

Almost all of the categories concerning the past referred to it as being related to memories and memory content (categories K24, K25, K27-K30; in total 44 statements) if not proposing identity between past and memory (category K24; n=8, 31% of participants). Memory was experienced as good, vivid or specific memory (category K30; n=6, 23% of participants). Memories of the past had shaped and influenced or had had an effect on their personality (category K27; n=12, 46% of participants), the valence of which varied ranging from primarily negative experiences of past recollections (category K28; n=4, 15% of participants) to a positive experience of past memories (category K29; n=11, 42% of participants). Accordingly, it was acknowledged that interpretations of past memories could vary (category K25; n=3, 12% of participants). The only category not directly or literally referring to the past as memories (category K26; n=5, 19% of participants) stated that the past was over and could not be changed.

3.4 Categories within the Group concerning the Future

The two most common categories were concerned with the future that was experienced as uncertain (category K31; n=14, 54% of participants) and that it had to be minutely planned accordingly (category K32; n=14, 54% of participants). The future was associated with fear, anxiety, and imminence (category K34; n=12, 46% of participants), but also with hope and pleasant anticipation (category K33; n=10, 38% of participants). Feelings of uncertainty and feelings of fear (categories K30, K34; in total 26 statements) seemed to covary: uncertainty in category K31 was related to a sense of fear (n=2), whereas expressing fear in category K34 was related to the feeling of uncertainty (n=3). Additionally, within the category concerning feelings of fear (category K34) three participants specified these feeling as being directed toward the near and immanent future. Accordingly, six statements (category 35; n=6, 23% of participants) generally divided the future into a near future and a more distant future.

4 Discussion

In Accordance with the TQ, we will discuss our analysis with regards to the flow or passage of time and the structure of time (past, present, future) for adults with ASD.

4.1 The Experience of the Passage of Time

The experience of the passage of time in individuals with ASD exhibits several features also associated with the experience of time in a population of individuals without autism (Vogel et al, in press). Just as in healthy individuals, time was experienced to pass or flow, to pass generally quickly, and to pass more quickly with increasing age. The participants with ASD described herein experienced changes in the passage of time depending on the affective imprint of a current situation: the experienced velocity of the passage of time would decrease in unpleasant situations, and increase in pleasant situations, just as healthy individuals reported (Vogel et al, in press). Surprisingly, in our qualitative approach there seemed to be no clear difference concerning the experience of time in individuals with ASD depending on the presence or absence of others or the interaction with others. A considerable number of statements explicitly denied any influence of social aspects on time experience. Due to the lack of a clear distinguishability between the experience of time during social situations and non-social situations through experiential accounts, we speculate, that it is not a social situation in itself which influences the passage of time, but that it is most likely the affective imprint of social situations which causes the passage of time to either speed up or slow down, just as reported for healthy non-autistic individuals (Vogel et al, in press). This does not principally rule out social interaction or intersubjectivity as a potential influential factor on time experience in ASD. Our method of employing a questionnaire is directed at experiences spontaneously reported by our participants. While we consider our data saturated (Sandelowski, M., 1995; Pope, C. et al. 2000; Mason, M., 2010; Glaser B., & Strauss A., 2017), the TQ cannot directly detect the more implicit aspects of time experience (Vogel et al., 2018a).

The first distinct revelation concerning the experience of the passage of time in ASD is the importance of one's personal *interest* and the ability to *delve into* an activity. Interesting activities caused the flow of time to speed up. Some individuals with ASD reported that activities also let the sense of time or the passage of time vanish or disappear. This observation was also reported during social interaction. This experience can be identified with what has been called *flow experiences* (Csikszentmihályi, 1990). Although these experiences may also be detected in healthy individuals (Vogel et al, in press), *flow* seemed to be of special importance to our participants with ASD. Due to its comparatively frequent appearance in the material (n=12), it can be speculated that the experience of timelessness associated with *flow experience* either may be a common byproduct to structure and routine behavior or even a generally more desirable state for individuals with ASD. This notion is further highlighted by reports of an unimportance of time (n=2), a generally bad sense of time (n=10) or the need to use clocks or other temporal aides to experience the passage of time (n=3). Accordingly, the inability of individuals with ASD to tell time, especially without clocks or calendars, repeatedly has been reported within the literature (Boucher, 2001; Boucher et al. 2007; Allman & deLeon, 2009).

Similarly, and as initially hypothesized, the implementation of structured behavior and routine were reported to be directly related to the passage of time (category K13; n=12). Routine, structured or stereotypical behavior and special interests made the passage of time more pleasant, suppressed the sense of time and prevented negative feelings.

In summary, the passage of time in ASD is experienced along four properties: First, it speeds up during pleasant activities including pleasant (social) situations; second, it may decrease during unpleasant activities including unpleasant (social) situations; third, it may vanish during interesting activities and interesting social encounters; and last, it may be experienced as more pleasant with structured behavior.

4.2 The Experience of Structure of Time

Concerning the three temporal dimensions of present, past, and future, we again found commonalities of experience between participants with ASD and a previous study on healthy individuals (Vogel et al., 2018a). Our material showed that the present had to be utilized and that it could be experienced or conceptualized both as extended in time or as a point in time.

However, several differences become apparent from our material. Whereas non-autistic individuals experienced the extension of the present as ranging from an activity (e.g. "I am presently reading.") to entire life phases (e.g. "I am presently retired") (Vogel et al., 2018a), participants with ASD seemed to restrict the present to a comparably fine-grained current activity. Furthermore, individuals with ASD described two different experiences of the present: either a snapshot-like momentary present or an extended duration of a meaningful activity.

This observed division of the present does not necessarily reflect incompatible experiential accounts because both demonstrate the interconnectedness between the three dimensions of time (Kupke, 2007; Kupke & Vogeley, 2009; Vogel et al., 2018a). The extended present in this context is a present that is undisturbed by sudden events befalling it from the future. Our data demonstrate that the future was experienced as uncertain and scary, with fear being predominantly associated with the near future. Whereas non-autistic individuals experienced both fear and hope directed towards one uniform future (Vogel et al., 2018a), participants with ASD differentiated between a "general" or far away future on the one hand, and a near future associated with imminence, uncertainty, and fear on the other hand. We speculate that the irruption of the near future into the present breaks up the ongoing present activity and leaves behind an isolated, momentary impression associated with feelings of unreality and surprise. It seems likely that this observation of fear of the near future reflects the considerable incidence of co-occurring anxiety in ASD (Bellini, 2004).

This interconnected experience of present and future is further accentuated by the inclusion of the experience of the past. Although largely similar to the experience of the past as significant for the development of personality and character, as well as its inherent pastness and unchangeability in healthy control persons (Vogel et al., 2018a), the overly prevalent reference to memory reveals a division of time into isolated events. Again, we propose that this division further exemplifies the interconnectedness of the various aspects of time. The near future's uncertainty and imminence are compensated for and reduced through the implementation of behavioral structure and routine. By excessively planning future events, the future and the present become more predictable and more pleasant. This external sequencing of time carries over into the past which is memorized accordingly as a highly structured sequence of events.

Consequently, the experience of the present may reflect the performance of the constructed temporal sequence. If the present is experienced as a sequence of meaningful and pleasant activities, structure and routine prevailed. If the present is experienced predominantly as a sequence of individual instants, structure and routine have failed as a compensatory mechanism. In line with these considerations, it previously has been suggested that the ability to uphold routines and the period of time which may be planned successfully reflects the level of functioning in ASD (Boucher, 2001; Fein et al. 2013).

If this construction of a temporal sequence succeeds and a plan works out or routine remains undisturbed, it is recognized by a pleasant feeling or faded experience of the passage of time, and an otherwise mostly absent feeling of security. This consideration demonstrates the interconnectedness of structure and passage of time into an ongoing structured directedness (Kupke, 2007; Kupke & Vogeley, 2009; Vogel et al., 2018a). Accordingly, it may be reasoned, that changes in the experience of the passage of time directly reflect changes of experience of the three dimensions of time (Vogel et al., 2018a; Vogel et al., 2018b). Vice versa, this observation explains the vulnerability of individuals with ASD to disturbances of their routines, a clinical feature commonly

observed and described by the primary symptom of “restricted, repetitive patterns of behavior, interests, or activities“ (American Psychiatric Association 2013, p.50).

Importantly, the structured directedness of time is not primarily disrupted. When focusing on the inner experience by means of introspection, or to a pleasant activity or situation, individuals with ASD appear to experience time comparable to individuals without ASD. The personally constructed routine remains intact and time passes regularly. In this case, the experience of time is undisturbed and may increase the frequency and intensity of *flow experiences*. Only when outside influences interrupt the self-imposed structure, the experience of time appears discontinued. We therefore propose the experience of time in ASD not to be *dis-rupted* or *fragmented*, as has been proposed for other psychiatric ailments (Wyllie, 2005; Fuchs, 2007; Gallagher, 2010; Allman & Meck, 2012; Moore et al., 2013; Moskalewicz, 2015a; Northoff & Stanghellini, 2016; Stanghellini et al., 2016; Yin et al., 2016; Fuchs & van Duppen, 2017), but to be *inter-rupted*. A descriptive psychopathology of the syndrome of *interrupted time experience* is presented in Table 3.

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Comparing these findings to the previous qualitative results from Zukauskas et al. (2009) we find that both are superimposable. Considering the “factual experience“ (p.95), the present as “prolongation“ of the past (p.104), the past as “fullest sense of time“ (p.103-104), and abundant references to structure and routine, we can identify these constructs within our material as well. However, the authors did not primarily include the experience of the passage of time into their analysis. Therefore, they were unable to describe the phenomenon of time experience in ASD in its entirety. Also, the reported “prolongation of the past“ into the present, would in our terms better be described as a prolongation of present and future into the past. It is not the past, which is prolonged into the present, but it is the structure within present and future which are reflected in the factual way the past is remembered.

4.3 Implications for Research and Treatment

Our observation of what we call *interrupted experience of time* in ASD leaves several implications. First and foremost the primary scope of our analysis of the inner time experience of participants with ASD was the data based identification of a comprehensive syndrome surrounding time experience in adults with ASD. An obvious follow-up study to this investigation could be the conceptualization and validation of a standardized questionnaire on time experience in ASD. A quantitative follow-up would also allow for complementary testing of variables potentially influencing the syndrome, such as e.g. gender and age.

Our qualitative findings cannot directly explain the putative underlying cognitive or neural mechanisms responsible for the examined variations in experience. The neural processes of Bayesian perceptual inference illustrated in the introduction may provide information and motivation for further neuroscientific investigation. We speculate that the comparatively slower integrative processes, correlating with (spatio-)temporal aspects of neural processes are disturbed in ASD and may be the cause of experiential disturbances (Hohwy et al., 2016; Vogel et al., 2018a), such as those reported herein. If according to the *hypo prior* hypothesis more time is needed to effectively come to a perceptual and experiential conclusion, and the surrounding circumstances do not provide the necessary time to do so, the underlying processes will literally be interrupted by the necessity to process the new and suddenly incoming sensory information. These interruptions will precipitate the experience of the passage of time as isolated, and momentary impressions one after the other. This will consequently lead to a conceptualization of time as comprised of isolated facts.

The emerging difficulties will be more pronounced in situations with rapidly changing and non-foreseeable perceptual input, such as e.g. social interaction. The compensatory mechanism to reduce surprise and anxiety is the introduction of self-constructed *priors* in the form of routine and plans.

In reference to psychiatric diseases the brain's resting state has been implicated to be the most suitable candidate to explain disturbances of time experience. In this context it has been suggested, that the temporo-spatial structure of the brains resting state may correlate to the temporo-spatial structure of inner experience and thus of psychopathological symptoms (Northoff, 2016a; Northoff 2016b; Northoff & Stanghellini, 2016). Further research on the spatio-temporal interrelationship through resting state studies may provide more detailed information on the implicit time experience not only in mental disease but also in ASD. As previous research has demonstrated differences within the Default Mode Network, i.e. the brains network primarily active during rest and idleness, between populations with ASD and non-autistic populations (e.g. Weng et al., 2010; Anderson et al. 2011; Joshi et al., 2017; Olivito et al. 2017), we may suppose that these features may very well be due to temporal disturbances.

Speculatively, an alteration in the Default Mode Network may be related to the results of this study, as it may be inferred from our data, that particularly idleness is not a desired state for an individual with ASD. It seems that a pleasant present is defined as an interesting and captivating activity. We may theoretically assume that the consequent effort to achieve an ongoing stream of pleasant activity and a reduction of future-directed anxiety, on a neuronal level may express a desired reduction in the activity of the Default Mode Network.

Apart from these diagnostic and research implications, an increased awareness of causes to suffering in ASD and a deeper knowledge of compensatory mechanisms as discussed herein may foster new therapeutic approaches, such as for instance instructions for structure implementation or training of general prospective planning capabilities.

5. Limitations

We conducted content analysis on 26 persons with ASD. We were able to identify a distinct experience of time in ASD. We infer from the analysis of our data that the explicit experience of time, open to conscious experience, is highly focused on implementing a stable structure and routine in order to decrease uncertainties lurking in the (near) future and to increase and stabilize present pleasantness. We surmise that depending on the level of cognitive function and the amount of external stressors the implemented structure succeeds or fails; in the case of failure causing distress and possibly descriptive autistic symptoms. We were able to explore and lay out in detail this syndrome of *interrupted time experience* in ASD. Our findings are heavily restricted to our specific sample of individuals with high functioning autism and exclusively describe inner experiences potentially affected by introspection impairments. The question of how this experience may be explained must be left open to speculation.

The method employed herein and the analysis of the collected material is limited to qualitative description and remains highly interpretative and vulnerable to oversimplification and false negatives. Despite their semi-quantitative report the results from this study constitute a qualitative account of time experience from adults with ASD. Frequency of responses does not illustrate a random sample measurement. Any comparison to results from other studies therefore must remain speculative, as statistical inference is not feasible. The postulated syndrome of *interrupted time experience* is not readily generalizable until it has been tested extensively. Accordingly we are unable to make any statement as to variance in symptom severity, presentation and occurrence. Although our analysis demonstrates and explains the features of *interrupted time*

experience and provides a coherent and applicable concept of primary and explicit experience of time in ASD, the underlying (unconscious) cognitive processes and neural mechanisms will be the focus of future research. With our findings, we hope to inspire a novel research principal investigating the interrelationship of alterations in time experience both on an experiential and a neuronal level, as well as the integration of qualitative research and neuroscientific research in general.

6. Compliance with Ethical Standards

This study received no additional funding. Each author declares that he/she has no conflicts of interest. All procedures performed were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

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Table 1: Demographics (Standard Deviation in Brackets)

Gender	m=18; f=8
Mean Age	41.6 (+-9.8)
Mean Years of Education	18.7 (+-4)
Mean AQ* (n=17)	42.0 (+-3.7)
Mean BDI**	12.9 (+-9)
Mean Verbal IQ	104.6 (+-9)

* Score above 32 indicates clinically significant autistic traits.

**Cut-Off Scores for BDI-II:
0–13: minimal depression
14–19: mild depression
20–28: moderate depression
29–63: severe depression.

	Table 2 Categorical System and Examples from the Material	
	The Passage of Time	
K01	During pleasant situations time passes quickly.	“Nice moments pass quickly.“
K02	During captivating activities time passes quickly.	“With deep occupation time passes quickly.“
K03	During captivating activities the passage of time is not felt.	“When I am occupied with special interests I do not feel the passage of time.“
K04	During unpleasant activities time passes slowly.	“Activities that are no fun seem long.“
K05	The passage of time is independent from the presence of others.	“In the presence of others nothing changes.“
K06	The passage of time varies.	“The passage of time fluctuates.“
K07	The sense of time is poor.	“I have hardly any sense of time. I lack a sense of time during everyday life.“
K08	Timing devices are needed to tell time.	“I need a watch to sense time.“
K09	With age time passes more rapidly.	“The years go by more quickly as you get older.“
K10	In the presence of others time passes slowly.	“With others time passes more slowly.“
K11	In the presence of others time passes quickly.	“In the presence of others time passes more quickly.“
K12	In the presence of others the passage of time is not felt.	“When others are around I do not pay attention to time.“
K13	Structure and routine influence the passage of time.	“With routine tasks time goes normal.“
K14	Time passes quickly.	“Time passes too quickly.“
K15	Time passes.	“The passage of time flows continuously without beginning or end.“
	The Present	
K16	The present has no duration/is not extended.	“The present is a point in time.“
K17	The present has a duration/is extended.	“The present is an extended interval.“
K18	The present is a current activity.	“The present is the period of time during which I dedicate myself to doing one thing.“
K19	The present is the current moment.	“The present is experienced as momentary.“
K20	The present is not real.	“The present is not graspable.“
K21	The present is a sanctuary.	“The present is experienced as positive because while in it I don’t have to fear anything.“
K22	Time has no deeper meaning.	“Time is not important.“
K23	The present has to be utilized.	“Every day has to be lived. Your own life has to be mastered.“
	The Past	
K24	The past is memory.	“The past exists in memory.“
K25	The past is variable.	“The past is constantly reevaluated.“
K26	The past cannot be changed.	“The past is simply over and cannot be changed.“
K27	The past shapes an individual.	“The past is a reservoir of experiences that can be used in the present.“
K28	The past is experienced negative.	“The worst part of time is the past because of the harrowing memories.“
K29	The past is experienced positive.	“The past stabalizes.“
K30	The past is remembered well.	“The past is very vivid.“
	The Future	
K31	The future is uncertain.	“The future is unknown and uncertain.“
K32	The future is being planned.	“I experience the future through planning. Safety through planning.“
K33	The future is full of hope.	“The future is full of possibilities. It is malleable, so you have to influence it.“
K34	The future scares.	“Because it is not foreseeable the future is connected to fear, worries, and
K35	The future consists of a near and a far future.	“The future is the possibility that something happens on short notice or on long notice.“
K36	Rest.	“Ticking Cuckoo clocks get on my nerves. Grandfather clocks with a gong are better.“

Table 3: Interrupted Time Experience

Experience	Definition	Relating Categories (% of participants)
The faded out passage of time.	The passage of time is hardly or vaguely felt. A bad sense of time. Fading is usually amplified by structured and routine activity.	K02 (35%), K03 (23%), K06 (19%), K07 (38%), K08 (12%), K12 (15%), K13 (46%)
The present as confined activity.	The present consists of one distinct activity, usually deemed important, necessary or meaningful. Routine is experienced as beneficial. Interruptions are experienced as distressing.	K18 (35%), K19 (42%), K18 (35%), K21 (15%), K23 (38%)
The past as isolated memories.	The past is described as a repetition of facts. Although meaningful and influential the past is not necessarily part of the lived present.	K24 (31%), K26 (19%), K27 (46%), K30 (23%)
The planned future.	The future is experienced as uncertain und frightening. The future is rigorously planned to avoid unexpected interruption.	K31 (54%), K32 (54%), K34 (46%), K35 (23%)

Figure 1. ***The Time Questionnaire:***

1. How do you experience the passage and flow of time?
2. Does the passage and flow of time change in the presence of other persons? If ‚yes', how?
3. Does the passage and flow of time change in relation to surroundings or situation (e.g. workplace, spare time)? If yes, how?
4. Does the present appear to be a point in time or an extended period in time? If you experience the present as an extended period in time, how long does the present last?
5. How do you experience the present and what does it mean to you?
6. How do you experience the past and what does it mean to you?
7. How do you experience the future and what does it mean to you?