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High tide or low tide

Reliving memories of emotional events

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Publication date

2023

[Link to publication](#)

Citation for published version (APA):

Duken, S. B. (2023). *High tide or low tide: Reliving memories of emotional events*. [Thesis, fully internal, Universiteit van Amsterdam].

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Um, we were in Madrid with my boyfriend and two of his friends and a girlfriend of mine. And we had just been out for dinner in La Latina in Madrid. And I was pretty drunk and so was my friend. And Susanne has never been drunk before that. And at a certain point we wanted to go back to the taxi, because I really could barely walk. And then the taxi wanted, I wanted to go to the taxi. But I was so drunk that at one point I walked into a billboard, fell to the ground, my whole leg was bleeding. And my friend who was very scared because she only knew me, and I was just completely gone, that she started crying really hard. And I just couldn't reassure her. And my boyfriend, that was the first time she had met my boyfriend, eh, he didn't know what to do either. And the taxis wouldn't take me because I was so drunk and they were afraid I would puke in the taxi. And um I felt very guilty because she was crying so much and I didn't want to scare her during our vacation, especially because she didn't know anyone in Madrid of course. Neither do I, except for my boyfriend and his friends. And his friends were gone by then too. And I felt so damn guilty but I just couldn't think straight because I was just so drunk and just lying on the floor at one point because I was just so out of it, I just couldn't walk anymore, couldn't stand up straight anymore, couldn't stand. And I wanted to give her a nice vacation because it was the first time the two of us went away. But I feel like I ruined it for her because her experience was so bad, because she really had to cry hard because I was so out of it.

Um this was on vacation with my boyfriend. Um the holiday where we also got together, that it became official. And it was really the day after that. We planned a very long walk. Um and most of the time the weather was very nice, but at one point it started to rain very hard. And then we reached this clearing in the mountains between the trees. And my boyfriend was walking in front of me. And suddenly he turned around to kiss me in the rain. And um that's still one of the most romantic things I've experienced. And every time I think back, I sort of get butterflies in my stomach.

Chapter 5

General discussion

People can mentally travel back in time and relive events from the past. Such reliving can include rich details about what happened when and where but also vivid perceptions and affective responses. This dissertation provided empirical evidence for affective psychophysiological responses that accompany the reliving of past experiences, distorted memory processes in people with depressive symptoms, and the malleability of emotional memories as a potential avenue for the prevention and treatment of memory distortions and mental disorders. We developed new experimental paradigms that do justice to the rich and complex nature of human experiences and the wealth of positive and negative emotions that accompany them. In the following, I will briefly summarize each chapter before contemplating on general conclusions that can be drawn across chapters on the reliving of emotional events in mental health and psychopathology. Throughout, I will highlight outstanding questions, and discuss implications for clinical practice.

In **Chapter 2**, we tested whether remembering naturalistic negative and positive episodes elicited corresponding psychophysiological expressions of affect. We developed a paradigm that allowed to investigate the encoding and retrieval of emotional episodic memories while measuring positive and negative facial expressions with fEMG. In two experiments, participants viewed positive, negative, and neutral movie clips and remembered them one day later as vividly as possible. Remembering positive movie clips elicited smiling responses. Remembering negative movie clips elicited frowning responses, but these were not larger than frowning while remembering neutral episodes. Hence, we found empirical evidence for the theoretical notion that episodic recollection can involve affective and psychophysiological responses that reflect the valence of the remembered event, but only for positive affect. Unexpectedly, the magnitude of affective responses when viewing the movie clips did not predict the magnitude of affective responses when remembering the clips, neither for positive nor negative episodes. While remembering emotional episodic memories can elicit psychophysiological expressions of positive affect, they do not seem to closely mirror or exactly re-instate the past affective response. It is therefore likely that the affective responses to memories do not only depend on the encoded episode but also on constructive retrieval processes (Kensinger & Ford, 2020; Schacter, 2012; Xiao et al., 2017). Such constructive imagery could allow to flexibly recombine and adjust mnemonic information depending on the goal of retrieval (Kensinger & Ford, 2020). Together, our observations provide empirical evidence for the notion that episodic recollection extends beyond the holistic retrieval of declarative memories and involves affective and constructive processes. Chapter 2 also provided the foundation for Chapter 3 and 4, by validating fEMG as a measure of the affective tone of memories, and by introducing a paradigm that allows the investigation of naturalistic episodes.

Chapter 3 evaluated evidence for overgeneral memory and negativity bias theories that could explain memory distortions. Both theories agree that people with depressive symptoms remember positive memories that are impoverished in episodic detail and emotionality. However, overgeneral memory bias predicts similarly diminished negative memories, whereas negativity bias theories predict enhanced negative memories. Participants with and without depressive symptoms relived negative and positive autobiographical memories, while we measured their affective responses and the number of retrieved episodic details. Whereas Chapter 2 only partially captured the multifaceted nature of episodic recollection by focusing solely on affective responses, Chapter 3 also assessed the remembrance of episodic details, thereby providing insights into the two core components of emotional episodic memories. Dysphoric participants remembered positive memories with less episodic detail, but negative memories with enhanced episodic detail compared to non-dysphoric participants. Moreover, they expressed profoundly diminished positive affect when remembering positive memories, but normal or possibly increased negative affect when remembering negative memories. These results were consistent with negativity bias but not with overgeneral memory bias theories (Disner et al., 2011; Gotlib & Joormann, 2010; Mathews & MacLeod, 2005; Matt et al., 1992). However, exploratory analyses suggested a plausible alternative account for affective memory distortions. Specifically, dysphoric individuals might experience positive attenuation (Rottenberg et al., 2005), that is, reduced affective responses to positive memories but normal affective responses to negative memories. It is further noteworthy that when participants experienced new emotional episodes, they showed a comparable pattern of affective distortions. This suggests that affective distortions in dysphoria may not be specific to memories, but result from general affective disturbances. Interestingly, while we found clear affective disturbances in psychophysiological expressions of affect (our primary outcome measure), we did not find any difference in self-report affect (complementary outcome measure) between dysphoric and non-dysphoric individuals. In sum, our results provided key insights into dysphoric memory distortions, and challenge important assumptions of prominent theories and memory therapeutics.

Chapter 3 shed light on theoretical explanations for memory distortions by comparing dysphoric and non-dysphoric participants, but it cannot provide insights into mechanisms that may lead to the rise and fall of memory distortions. **Chapter 4** investigated whether the affective tone of memories can change, thereby providing a potential explanation for how memories might become overly negative in the aetiology of mental disorders, as well as how memories might become more positive in treatment. Specifically, we tested whether the affective tone of an initially neutral episodic memory can change when it is reactivated in combination with new emotional information. While we found evidence that the affective tone of episodic memories can change from neutral to positive and from

neutral to negative, the results were not unequivocal, and the magnitude of the updating was not large. There might be other ways to change the affective tone of memories that are more effective. For example, imagery rescripting or cognitive reappraisal aim at changing the meaning of complex episodic memories, therefore possibly fundamentally changing the emotional impact of memories (Arntz, 2012; Speer et al., 2021).

Affective psychophysiological responses when reliving naturalistic events: evidence and methodological considerations

One of the central hypotheses of this dissertation was that reliving complex emotional events elicits affective psychophysiological responses. Specifically facial expressions are representative of positive and negative valence and are thought to be tightly linked to action tendencies (Adams et al., 2006; Frijda & Tcherkassof, 1997; Lang & Bradley, 2010; Scherer, 2009). In line with this hypothesis, we found consistent evidence that remembering positive events elicited strong smiling responses, regardless of whether the remembered events were real autobiographical experiences or movie clips (Chapter 2, 3, and 4).

Frowning responses to negative memories were only pronounced and different from neutral episodes when investigating autobiographical memories (Chapter 3), but not when investigating memories of movie scenes (Chapter 2 and 4). Considering that personal negative autobiographical memories did elicit strong psychophysiological expressions of negative affect, a plausible explanation is that the memories of the movie clips were simply not emotional enough to elicit strong frowning responses. While remembering negative autobiographic memories and viewing of negative movie clips elicited strong affective responses, memories of the negative movie clips might be somewhat less emotional. This notion is also in line with research on the fading affect bias, that is, affect associated with negative events fades faster than affect associated with positive events (at least in healthy individuals; Walker, Skowronski, Gibbons, et al., 2003; Walker, Skowronski, & Thompson, 2003). However, methodological considerations might also explain the absence of frowning responses to weak negative memories. Specifically, frowning is not only an indicator of negative affect, but can also reflect cognitive effort (B. H. Cohen et al., 1992). In the movie paradigms, remembering neutral clips was relatively difficult (also represented in lower memory vividness ratings in the neutral condition), which resulted in frowning responses to memories of neutral clips. Therefore, required cognitive effort to remember neutral memories might partially explain the lack of evidence for negative expressions. In the autobiographical memory study, the negative memories were inherently more self-relevant and emotional than in the movie paradigms, and the amount of cognitive effort required to remember each episode was reduced to a minimum because participants self-selected cues that

would unambiguously trigger each memory. Consequently, the autobiographical memory study (Chapter 3) did provide strong evidence for psychophysiological expressions of negative affect when reliving negative experiences. In sum, our studies therefore show that the retrieval of complex positive and negative memories elicit corresponding psychophysiological expressions of affect. However, when using fEMG of the corrugator as a readout for negative affect, future studies should carefully balance the required effort to retrieve memories across conditions.

The notion that some memories in the movie paradigms were not powerful enough to elicit clear psychophysiological responses also bears consequences for designing future experiments. Specifically, if memories of rich negative movie scenes can fail to elicit pronounced affective responses, it seems unlikely that paradigms that employ other low-intensity emotional stimuli (e.g., emotional words or pictures) can model the impact of episodic memories on affective states, behaviour, and well-being. The observation that personal autobiographical memories do naturally elicit psychophysiological expressions of affect suggests that it is necessary to use intense and possibly self-relevant emotional stimuli to model the holistic re-experience of complex emotional events.

The finding that participants displayed positive and negative facial expressions when reliving memories is particularly striking considering that participants in all studies were seated alone in a room in front of a computer screen. This is an important methodological feature because in social situations people tend to show more pronounced facial expressions driven by attempts to communicate (Crivelli & Fridlund, 2018; Gehricke & Shapiro, 2000; Hess, Banse, & Kappas, 1995). In our studies, however, facial expressions were stripped of all communicative value and are therefore likely to represent inner affective states. Future studies should likewise limit the social context in which facial expressions are displayed to allow for strong conclusions on inner affective processes, except of course when the social function of facial expressions is part of the research question.

In the introduction of this dissertation, I have highlighted that most research to date investigated the effect of emotions on episodic memory but not the other way around. Our findings demonstrate that retrieving episodic memories also changes affective states. Given that emotional processes change motivational propensities and prepare for actions, it is plausible that it's precisely the affective states associated with past experiences that influence people's behaviour and well-being. The paradigms presented in this dissertation offer promising tools because they enable the quantification of affective responses through psychophysiological indices in addition to self-reported feelings. An interesting next step for emotional episodic memory research will be to test the effect of emotional episodic memories on people's behaviour inside and outside of the lab, and ultimately to illuminate the mechanisms that underly the relationship between emotional memories and mental health.

Psychophysiological expressions of affect, subjective feelings, and episodic detail represent distinct memory components

According to componential emotion theories, emotions comprise a range of subsystems that include an external or internal elicitor (e.g., a memory), appraisals of this elicitor, motivational change or action tendencies, psychophysiological responses and motor expressions, and finally subjective feelings that emerge from a combination of these components (Scherer, 2009; Verduyn, Delaveau, Rotgé, Fossati, & Van Mechelen, 2015). Even though these components interact, they represent partially independent processes (Scherer, 2009; Verduyn et al., 2015). Consistent with this notion, we found evidence that psychophysiological expressions of positive and negative affect in response to memories did not align closely with self-reported subjective feelings. In Chapter 2, there was no correlation between zygomaticus responses and self-reported positive feelings, nor between corrugator responses and self-reported negative feelings. In Chapter 3, we found pronounced dysphoric distortions when investigating psychophysiological expressions of affect, but not when investigating self-reported positive and negative feelings. In sum, facial expression assessed with fEMG and self-reported positive or negative valence seem to measure somewhat different components of emotions that are elicited by remembering past episodes.

While facial expressions are relatively automatic and closely linked to motivational tendencies, subjective feelings represent a meta-level that relies on higher-order cognitive processes that allows the categorization and labelling of emotions (Frijda & Tcherkassof, 1997; Scherer, 2009). When facial expressions of affect are distorted in psychopathology, this might imply different problems in affective processing than when self-reported feelings are distorted. For instance, in Chapter 3, we found evidence that dysphoric individuals express less positive affect compared to non-dysphoric participants. This suggests that aberrant affective responses in dysphoria might already begin at a relatively early and automatic processing stage, rather than at later reflective cognitive stages. In other words, the affective distortions in dysphoria might arise from aberrant basic processing of emotional information rather than from higher-order cognitive processes that are involved in reflecting on one's subjective affective state. However, dysphoric participants reported similar positive affect as non-dysphoric participants. This might indicate a lack of introspection or awareness of aberrant affective processes, in addition to altered automatic affective processes. The discrepancy between psychophysiological expressions of affect and subjective feelings highlights the importance of incorporating measures other than self-report in studies on aberrant emotional processing in psychopathology.

Next to the observation that psychophysiological expressions of affect and subjective feelings do not always align, we also found evidence that affective responses to autobiographical memories (measured with fEMG or self-report) were independent from the number of episodic details that participants remembered. This indicates that different components of emotional episodic memories might rely on at least partially independent psychobiological processes. Consequently, if one aspect of a memory is retrieved successfully (e.g., episodic details), that does not imply that other aspects are retrieved equally well (e.g., affective responses). This is in sharp contrast with common assumptions of emerging therapeutics that aim to alleviate depressive symptoms by treating memory distortions. Specifically, it is assumed that increasing the availability of episodic details of positive memories would lead to similar increases in positive affect when reliving memories (Arditte Hall et al., 2018; Werner-Seidler & Dalgleish, 2016). However, the absent relationship of detail and affect in our data (even in non-dysphoric control participants) suggests that this might not be the case.

The observation that different readouts of the reliving of memories are not strongly correlated also has important implications for empirical memory research. Specifically, if different memory components are not strongly correlated, manipulating one memory component might not have effects on other components. That is, experimental manipulations that have a great impact on the number of retrieved episodic details, might not have a similarly large impact on the affective response to the memory. Likewise, manipulations that change the psychophysiological expressions elicited by memories might not change subjective feelings and vice versa. Future research could delineate more carefully how different memory components relate to each other, and what memory components are being targeted by current memory therapeutics. Our paradigm in Chapter 3 would provide a valuable tool to measure a variety of memory components and how these are related to each other, including psychophysiological indices of affect, subjective feelings, memory detail, but also other cognitive factors such as the perspective that one remembers an episode from (i.e., first person or bystander perspective). For emerging memory therapeutics, it will be important to either identify which memory distortions play the most important role in depression, or to take a comprehensive approach and aim to reduce multiple memory distortions at the same time (i.e., altering not only the amount of episodic detail but also the affective impact of memories). It is noteworthy, however, that dysphoric individuals seem to not only suffer from affective distortions when remembering emotional episodes, but also when experiencing new emotional events. Therefore, affective memory distortions might not arise from memory processes but from more fundamental biases in affective processing. Treatments that alter affective processing independent of whether the eliciting event is a memory or not might be more effective in alleviating the burden of depression, because they would not only retrospectively

treat maladaptive memories but also help to experience more pleasure and reward in the present and the future.

The importance of positive affect in mental health and psychopathology

Across studies, we found more pronounced affective psychophysiological responses to positive episodes than to negative episodes. This is interesting in the context of psychological science that traditionally focuses on negative affect (Carl, Soskin, Kerns, & Barlow, 2013; Craske, Treanor, Dour, Meuret, & Ritz, 2019; Garland et al., 2010; Seligman, 2019). Indeed, psychological functioning and mental health are often considered in terms of the absence of negative or maladaptive processes. In the last two decades, this approach has been challenged and it has been suggested that to understand both normal as well as pathological mental processes, it is important to consider the role of positive affect as well as other abilities, states, and traits that promote a joyful and satisfied life (or a life with a healthy balance of positive and negative experiences; Carl et al., 2013; Craske et al., 2019; Garland et al., 2010; Seligman, 2019). Our data support this notion that positive affect and mental processes that bring joy are important and potentially powerful factors on driving human behaviour. The experiences people have in their lives involve both high and low tides, and if we aspire to understand what drives people in health and disease, it is important to investigate both sides to our lives and mental processes.

Chapter 3 showed that people with and without depressive symptoms express positive affect while experiencing and while remembering emotional events. However, positive expressions in people with depressive symptoms were profoundly diminished. In a way, the pronounced difference between the two groups was surprising – even though we expected a difference, we did not expect it to be that strong. In contrast, differences in negative affective expressions between the two groups were a lot smaller or even absent. This suggests that an inability to experience and express positive affect might play an important role in depression. It seems likely that if people do not experience positive affect and cannot reinstate the joy from past experiences with their minds and bodies, that this affects their behaviour and well-being. It might for example reduce one's willingness and ability to seek out and experience positive events, contributing to a downward spiral where diminished positive affect leads to a reduced motivation to seek out positive experiences and vice versa (Dimidjian et al., 2008; Garland et al., 2010). These considerations align well with recent calls to acknowledge the role of anhedonia (the inability to process reward and pleasure) in the study and treatment of depression (Dimidjian et al., 2008; Pizzagalli, 2022; Werner-Seidler, Banks, Dunn, & Moulds, 2013). The importance of anhedonia in depression also aligns with the idea that diminished positive expressions of affect reflect aberrant processing at a relatively early and automatic stage of affective

processing. That is, depression might be characterized by fundamental difficulties to experience pleasure and reward, rather than or in addition to negative cognitive processes. Treatment for depression could therefore include interventions that aim at increasing someone's motivation and ability to experience positive events and emotions. Interestingly, several available treatments that aim to alleviate depression might be effective because they increase the willingness to engage in positive experiences (e.g., behavioral activation therapy, Dimidjian et al., 2008) or the ability to process positive information and reward (Admon & Pizzagalli, 2015; Harmer et al., 2009; Walsh & Harmer, 2015). However, even though these treatments can be effective for some individuals in the short-term, they do not work for many patients and often their effects are not maintained in the long run. A major challenge for psychological research remains to find ways to persistently alter affective processes to prevent and treat recurrent depressive episodes.

Reflections on implementing open science practices

Finally, throughout the empirical work in this dissertation we aimed to adhere to the best possible scientific practices that are currently available. Over the course of the doctoral project, we progressively increased the openness and rigor of our work. The implementation of open science practices likely increased the quality and credibility of our research (Chambers & Tzavella, 2022; Munafò et al., 2017; Wagenmakers, Wetzels, Borsboom, van der Maas, & Kievit, 2012). For instance, open data and code make our results reproducible, allowing other scientists to quickly build on or replicate our experiments. Perhaps even more important than data and code sharing is the preregistration of confirmatory research (Nosek et al., 2019; Wagenmakers et al., 2012). Especially in Chapter 3, we defined all hypotheses and analyses in meticulous detail, to the extent that even most code for the analyses was written before data collection started. In the end, our data showed that dysphoric individuals experienced profound distortions when investigating psychophysiological expressions of affect, but there was no difference in self-reported feelings between dysphoric and non-dysphoric individuals. The preregistration clearly demonstrates that the psychophysiological responses were our primary outcome variable. This should give other researchers confidence that we did not post hoc cherry pick the outcome variable that yielded the most interesting results as the focus of the manuscript, but that we a priori selected the variable that was most pertinent. The registered report format even allowed other scientists to comment on our work before we started data collection, rather than only pointing out limitations after the study had already been conducted. This allowed us to improve our design based on expert input before preregistration and data collection, ultimately resulting in a study of higher quality.

Adhering to best possible scientific practices such as sharing of data and code or preregistration has obvious benefits and increases the transparency, robustness, and possibly impact of our experiments (McKiernan et al., 2016; Nosek et al., 2015). However, these benefits do not come without costs, and we faced several challenges when implementing them. Most importantly, conducting rigorous open research, including detailed preregistrations, takes a lot of time, while time is perhaps the scarcest resource in academia where most PhD and postdoctoral contracts do not extend more than 4 years. When choosing a registered report format, the time it takes to conduct a project is even further increased through the editorial and review process that requires empirical work to be put on hold for months. Indeed, it was only possible to finish the registered report in Chapter 3 because the project was relatively well-funded and because one of my supervisors acquired additional funding. When it became apparent that it might not be possible to finish the registered report within my appointment at the University of Amsterdam, we could therefore substantially increase the expenses for subject recruitment (e.g., with advertisements on social networks) and hire research assistants to speed up data collection. In any setting with less funding or stricter limits to expenses, Chapter 3 would therefore not have been possible to finish. This implies that some open science practices are reserved for a limited number of well-funded research groups, which ultimately is a threat to the diversity of approaches and ideas in science (Devezer, Nardin, Baumgaertner, & Buzbas, 2019).

Given the amount of time and financial resources required for the studies in this dissertation, it seems even more important that their materials, data, and results are made publicly available. With considerable effort, we managed to collect a rich high-quality dataset over the course of almost half a decade. It would be a waste if these data could not be used in full to inspire future projects on emotional episodic memories. However, the fact that collecting high quality data often takes several years can be problematic for individual researchers because the current incentive structure of science requires people to publish as much as possible as quickly as possible to be able to continue to work in science. Job and funding decisions are to a large extent driven by the number of publications of individual researchers (Fanelli, 2010; Rawat & Meena, 2014). If the incentives in academia do not change, this might encourage the use of existing data over generating new data, which could result in many papers and claims based on a few datasets. However, if observations cannot be replicated in multiple datasets with and without variations in study design, it is impossible to establish their robustness, possible boundary conditions, and ultimately their theoretical and practical value (Hendrick, 1990; Hüffmeier, Mazei, & Schultze, 2016). Likewise, testing many research questions on only one or a few datasets could inflate the number of false positive findings.

In sum, open science practices can improve the quality and impact of individual studies as well as scientific research as a cumulative whole. However, implementing practices such as data sharing or preregistration also requires additional resources which can conflict with the incentive structure in academia. To promote rigorous and transparent research, it might therefore be necessary to re-evaluate the academic incentive structure and to reflect on ways to encourage researchers to keep generating valuable open data. There is indeed an increasing number of initiatives, funding bodies, and universities that promote a re-evaluation of how individual scientists and their work should be assessed (see for example the San Francisco Declaration on Research Assessment, <https://sfdora.org>). Similarly, it will be important to fairly allocate resources, so that best scientific practices are not reserved to a small elite of well-funded research groups.

Conclusion: An ode to the richness of emotional experiences and the ability to relive them

This dissertation showed that memories of emotional events elicit affective psychophysiological responses, and that the affective tone of memories can change when people encounter new emotional experiences. We also showed that people with depressive symptoms retrieve memories that are distorted in content and affect, which might contribute to the onset and maintenance of clinical depression. Together with my supervisors and collaborators, we developed paradigms that embrace the holistic and experiential nature of episodic recollection and hopefully inspire future research on naturalistic episodic memories. When reading the memories of participants presented throughout this manuscript, I cannot help but to feel as if I'm reliving the experiences with them. This gives me confidence that we achieved to capture the rich nature of episodic memories as they allow us to re-experience the high and low tides of our lives.

Um, the first image I see in front of me is, erm, that I am standing behind a table. And that I'm standing in the room where my father is on my right - or my father is lying in a coffin. And there is a sea of flowers. And opposite of me, um, there are all the people, all the people I know. And I'm singing a song. Um, at the funeral. Um, and I kind of feel like, it kind of looks like I'm looking through, Um like I'm looking through um, some fog or so. So I can't see very well. Um, I'm overwhelmed by the sadness and I feel very woolly. So I can't think very well and it kind of feels like I'm in a dream, in a dream standing there. Um, and the next moment I saw before me was that we are carrying the coffin through the garden to the same room with, um my family. Um, that's a green one, okay.

Um, this memory was, um, when I had just finished my thesis presentation. Um, or rather, yes, when I finished it. Um, so that actually meant at the end of, of my thesis for me, of my master's thesis. And I was upstairs. My parents were downstairs. I had given the presentation upstairs, so to speak. And um, I closed the laptop and my parents came running upstairs and said, "Oh, you've done so well, it's, um, so good, and now you're finally done. How good, how good." And they were so proud, and they were so happy for me. And I was so happy. And my brother called, because he was in Berlin. And he called, he had also watched the presentation and he called: "You did a good job, and blab la bla" and um yes, I just felt very loved and, um, like they were proud of me. And that was very nice. Um, because sometimes I start to doubt myself. So I was really pleased to hear, um, yes, that they thought it went so well and that I had done so well. And um yeah, it was just really sweet. And um, and then we went to eat cookies that my mother baked. And um, that was just a very, yeah. It's nice to finish it and that people are proud of you. And I felt very, um, yes, relaxed at that moment.