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Review

Event Perception: Translations and Applications☆

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Event segmentation is the parsing of ongoing activity into meaningful events. Segmenting in a normative fashion—identifying event boundaries similar to others' boundaries—is associated with better memory for and better performance of naturalistic actions. Given this, a reasonable hypothesis is that interventions that improve memory and attention for everyday events could lead to improvement in domains that are important for independent living, particularly in older populations. Event segmentation and memory measures may also be effective diagnostic tools for estimating people's ability to carry out tasks of daily living. Such measures preserve the rich, naturalistic character of everyday activity, but are easy to quantify in a laboratory or clinical setting. Therefore, event segmentation and memory measures may be useful proxies for clinicians to assess everyday functioning in patient populations and an appropriate target for interventions aimed at improving everyday memory and tasks of daily living.

Keywords: Event perception, Everyday memory, Activities of daily living, Remediation, Intervention, Rehabilitation

General Audience Summary

People spontaneously parse ongoing streams of action into smaller, meaningful units of activity. This spontaneous parsing takes place outside of awareness, but can be brought to awareness if people are asked to explicitly segment an ongoing activity. There is generally good agreement across individuals regarding where these boundaries lie, but there is also a large degree of inter-individual variability in being able to identify these normative boundaries between units of activity. These individual differences matter: People that are better at identifying normative boundary points show better memory for the activity they just saw and carry out everyday tasks more efficiently. We discuss the potential utility of testing everyday event understanding and memory in the clinic to gain insight into the patient's ability to carry out everyday tasks and remember ordinary information from everyday life. We also suggest designing interventions that target event segmentation ability. In contrast to interventions aimed at training working memory capacity, processing speed, or visual attention in isolation, these materials and tasks are close to those that are important for everyday living. For this reason, they merit investigation as potential bases for improving cognition outside the laboratory.

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Events are fundamental to everyday existence, and events are structured. Suppose an observer were to see someone in a kitchen apply heat to a kettle, place a mug on the counter, put a teabag into the mug, and add hot water. Most of us would easily understand these behaviors as a series of steps carried out in pursuit of the larger goal of making tea. If we could not identify the appropriate segments of activity, chances are this would indicate that we did not comprehend what was happening and thus might remember it poorly. Further, it might indicate that we were ill prepared to act appropriately—say, if offered a cup. In this article, we will develop a proposal suggesting that by measuring how a person segments activity we can easily and robustly diagnose aspects of their ability to understand events, to remember them later, and to act appropriately. We also propose that by intervening to improve one's segmentation of an activity, we may be able to instantiate improvements in their event comprehension, memory, and everyday action performance.

We take events to be defined in psychological terms: "a segment of time at a given location that is conceived by an observer to have a beginning and an end" (Zacks & Tversky, 2001, p. 17). They make up a lot of the everyday stuff of human experience—from making breakfast to getting a haircut to shopping for groceries to walking one's dog. They are composed of entities and relations organized in a spatiotemporal framework (Radvansky & Zacks, 2014). They also are composed hierarchically: coarser-grained events are made up of finer-grained events. For example, a "changing a tire" event might break down into "jacking up the car," "removing the flat tire," "taking out the spare," and so forth. One point worth emphasizing about this definition of events is that it restricts them to being spatiotemporally contiguous. For example, by this definition "doing laundry" is an activity but not an event, because it is interrupted while the washer and dryer are running. Rather than being a single event, the laundry activity is made up of a set of events that are connected by causal and thematic links.

There is good agreement among participants regarding the boundaries, or transitions, between units in an ongoing event (Newtson, 1976). Parsing an activity in a normative fashion predicts how much participants subsequently remember about that activity (Bailey, Kurby, Giovannetti, & Zacks, 2013; Kurby & Zacks, 2011; Zacks, Speer, Vettel, & Jacoby, 2006) and also predicts the quality with which individuals perform everyday actions (Bailey et al., 2013). These findings point to the possibility that event segmentation can serve as a proxy for performance in a variety of real-world tasks. Because both memory for everyday activities and the ability to carry them out are important factors in maintaining independence in older adulthood in particular, interventions aimed at training individuals to perceive events normatively may help individuals maintain independence at a point in the lifespan when the ability to live independently can be in jeopardy.

'Realism' and the Challenge of Transfer in Cognitive Interventions

Many flavors of cognitive interventions, from task-switching to mnemonic training (see Verhaeghan, Marcoen, & Goossens, 1992 for a review) and working memory training (see Morrison & Chein, 2011; Shipstead, Redick, & Engle, 2012; Simons et al., 2016 for recent reviews) have demonstrated limited generalization beyond the task that is trained in the laboratory. One often sees *near transfer*—improvements in tasks very similar to the practiced task, but little evidence for *far transfer*—improvements in tasks that are conceptually related to the training task but differ from the training task in terms of the major cognitive skill(s) taxed (Morrison & Chein, 2011). For example, if one trained on a working memory task using letter stimuli, transfer to another working memory task with number stimuli would constitute near transfer. Farther transfer might entail a task that taxes long term memory or attention rather than working memory. However, both of these types of tasks are quite near to the training domain in comparison to the ultimate target of most cognitive training interventions: improving cognitive functioning in everyday life. To date, most cognitive training studies have used measures of relatively near transfer, with the hope that the training regimen being studied will ultimately produce far transfer to activities that matter in daily life (see Richmond, Morrison, Chein, & Olson, 2011 for a discussion of the importance of using ecologically valid transfer measures).

The ability to perceive an event in such a way that it supports later memory for the event is critical for many everyday activities. For example, most older adults need to be able to recall the event of taking their medication in order to avoid double dosing or missing a dose. Parsing the everyday activity of medication administration in such a way that it facilitates memory for medication adherence is of obvious utility. Further, segmentation ability is related to efficient action execution. In one study, participants segmented three movies depicting everyday activities (a woman making breakfast, a man preparing for a party and a man planting window boxes), and then were given instructions to perform a different set of everyday activities (packing a child's lunch box and backpack). Participants who better segmented the activities depicted in the videos exhibited better performance of the lunch box-and-backpack enactment task (Bailey et al., 2013). This, together with the finding that segmentation of one activity predicts not just memory for that activity but memory for other activities (Kurby & Zacks, 2011), suggests that normative segmentation is important not only for later memory but for performing everyday actions in an appropriate manner. We propose that because event segmentation overlaps with everyday activities in their cognitive processes and in their surface features, training regimens targeting event segmentation may better transfer to everyday activities than other laboratory tasks. In other words, the domain of event perception is much nearer to the types of everyday tasks participants often hope to improve by engaging with cognitive training. Therefore, event segmentation is a particularly attractive target for cognitive remediation.

Event Segmentation Theory

Event segmentation theory (EST) provides an account of how ongoing activity is segmented into events during everyday action perception and performance (Radvansky & Zacks, 2014; Zacks,

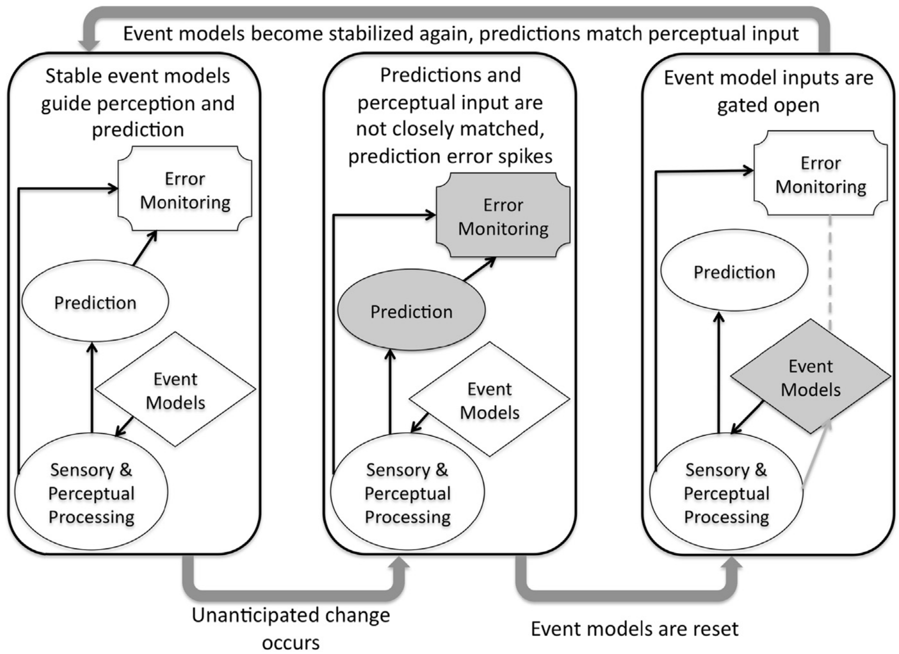

Figure 1. When perceptual input and predictions are closely matched, event models are stable. When an unanticipated change occurs, predictions and perceptual representations share few overlapping features, leading to a spike in prediction error (see gray highlight). This leads the event model to be reset and to allow inputs to the event models to be gated open (see gray highlight). Eventually, event models settle back into a stable state.
Adapted from "Segmentation in the perception and memory of events" by C. A. Kurby & J. M. Zacks, 2008, *Trends in Cognitive Science, 12*(2), p. 73.

Speer, Swallow, Braver, & Reynolds, 2007; Zacks & Tversky, 2001). Briefly, EST posits that we parse ongoing events into smaller, more manageable units. These events are maintained in working memory as mental representations called *event models* (Zacks et al., 2007, see Figure 1). Maintaining an event model is adaptive, in part, because it allows one to make better predictions about what will happen in the near future, and thus to effectively plan and control actions. According to EST, boundaries are perceived when one's predictions are violated (Speer, Zacks, & Reynolds, 2007; Swallow, Zacks, & Abrams, 2009; Zacks, Kurby, Eisenberg, & Haroutunian, 2011). At these points, one's event model is updated to include new information gleaned from perceptual input. This updating process amounts to a focal deployment of processing resources; thus, updating can be viewed as a form of attention (Zacks et al., 2007). Event models are maintained at a range of timescales, ranging from *fine-grained* (less than a second to a few seconds) to *coarse-grained* (tens of seconds).

To make this more concrete, imagine observing someone making his or her bed in the morning before heading to work. There are distinct steps in the activity of making the bed, which might include pulling up the sheet, smoothing the comforter, fluffing the pillows and placing them at the head of the bed. These larger units might be thought of as coarse events, whereas grabbing the sheet, pulling it up and straightening it out might constitute fine events making up the larger 'pull up the sheet' coarse event. When the actor engaged in the activity is in the middle of grabbing the sheet, her or his movements are highly predictable based on the constraints of the bedclothes, the viewer's knowledge about bed-making, and regularities in biological motion. At the end of the pulling-up, the activity is likely to become transiently less predictable, perhaps resulting in a prediction error spike. This timepoint might be marked as a fine-grained event boundary for the viewer. At the point when the sequence of actions is completed and the sheet has been pulled up, the activity is yet less predictable: the actor might choose to fluff the pillows, smooth the comforter, or even fold a blanket and place it at the foot of the bed. This is likely to lead to the viewer to experience a coarse event boundary. Fine-grained boundaries tend to be associated with performing different actions on the same object, whereas coarse-grained event boundaries are detected on the basis of interaction with different objects (Zacks & Tversky, 2001).

Schemas are one type of cognitive representation that can influence sensory and perceptual systems so as to bias attention to relevant information. When the event is proceeding as expected, as in the fluffing the pillows subgoal outlined above, observers experience low levels of prediction error. The relatively close match between perception and prediction is one of the characteristic features of event middles. At middles, the activation of schemas allows observers to reduce attention to external stimuli (Brewer & Lichtenstein, 1981). When an event boundary is experienced, event models are reset. In addition, observers may bring in other event schemas in order to gather additional information about the actors' goals and subgoals in the moment if the mismatch between schema and perception is very high. For example, if after smoothing the comforter the actor turned to the ironing board, an observer might activate an 'ironing clothes' schema to direct attention to the new overarching goals and subgoals of the activity.

Event boundaries involve a convergence of bottom-up and top-down processing and are thought to be psychologically

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privileged. In fact, evidence suggests that event boundaries may serve as anchors for memory. Event boundaries are better remembered than other points of events (Newtson & Engquist, 1976). Movies stripped of their boundaries are not remembered as well as a film presented without the more-predictable midpoints (Schwan & Garsoffky, 2004). Knowing that the goal of the actor is to make the bed allows one to filter out features known to capture bottom-up attention, such as irrelevant motion (such as the movement of a ceiling fan) or visual pop-out (a red pillow in an otherwise totally blue room; see Aston-Jones & Cohen, 2005; Bouret & Sara, 2005; Grossberg, 2005; Zacks et al., 2007 for a discussion of features that lead to attentional capture).

In addition to perceptual input driving the identification of event boundaries, the activation of event schemas can serve as another mechanism to allow individuals to identify points at which prediction error is likely to be high, which in turn allows the event model to be updated (Sargent et al., 2013). For example, in watching the making-the-bed scene, a knowledgeable observer can generate a script that describes the typical sequence of steps in making the bed. At transitions between steps, such as the actor pulling up the sheet and then moving on to fluffing the pillows, the script is more likely to deviate from the actual activity than within a step, such as when the actor first touches the sheet. When these potential mismatches are likely to occur the observer should pay close attention to the activity and allow the observed sequence of actions, rather than what was predicted to happen according to the script generated by the observer, drive the updating of event models.

Why Intervene?

Previous cognitive training interventions in the area of memory and attention have not demonstrated any influence on comprehension of and memory for everyday activities such as remembering directions or preparing a meal (Kelly et al., 2014). As Kelly and colleagues rightly note, these effects are understudied in the current literature, but the available evidence for benefit in this domain is not compelling (Kelly et al., 2014). Interventions that are designed to target event comprehension would make direct contact with many of the cognitive complaints made by individuals in the clinic (Galvin, Roe, Coats, & Morris, 2007). Often times these complaints will take the form of difficulties in remembering, executing, or attending to everyday activities. These complaints might include things like remembering names, how to get to new places, or following the plot of a movie or television show (Galvin et al., 2007). Many of these processes are related to, and are supported by, normative event perception (Kurby & Zacks, 2008).

Though cognitive processes such as episodic memory and semantic knowledge are related to event comprehension, the extent to which individuals can meaningfully parse ongoing activity uniquely predicts subsequent memory for the event. In one study involving a broad sample of adults from 20 to 79 years of age (Sargent et al., 2013), event segmentation predicted event memory after controlling for age, education and psychometric measures of cognitive ability including processing speed, working memory capacity, laboratory episodic memory, and general knowledge. Segmentation ability also predicts memory in individuals with neurodegenerative conditions such as Alzheimer's disease (Bailey et al., 2013; Zacks et al., 2006). Event memory also depends on one's semantic knowledge about events. In the study by Sargent and colleagues, event knowledge predicted event memory independently of event segmentation, and independently of the psychometric measures. Most interesting is that event knowledge predicted event memory after controlling for general knowledge; this suggests that there are specific knowledge representations for events that support effective event encoding and retrieval (Sargent et al., 2013).

Beyond Alzheimer's disease, the ability to parse events in a normative fashion is also relevant for functional outcomes in other clinical populations such as schizophrenia. One of the hallmark impairments of schizophrenia is working memory deficits (Heinrichs, 2005). Relative to controls, individuals with schizophrenia are impaired on coarse segmentation but not fine segmentation (Zalla et al., 2004). A similar pattern is seen in individuals with frontal lobe lesions (Zalla, Pradat-Diehl, & Sirigu, 2003) and in those with traumatic brain injury (Zacks, Kurby, Landazabal, Krueger, & Grafman, 2016). The selective impairment in identifying normative coarse boundaries suggests that individuals with schizophrenia and frontal lobe lesions may have difficulty utilizing script knowledge, but may have preserved event models (Zacks & Sargent, 2010). The relationship between event comprehension and subsequent memory for the activity in healthy individuals provides the basis for a theoretically and practically important program of research on intervention strategies that could be employed in populations with deficits in event memory. Work in this vein could elucidate the role of event segmentation measures in both event memory and functional independence in clinical populations.

The relationship between normative event segmentation and efficient action execution (Bailey et al., 2013) suggests that interventions targeted at improving event understanding may not only have a positive effect on this ability, but may also lead to improvements in execution of everyday activities as well. Efficient action execution has been shown to predict the ability to live independently (Giovannetti et al., 2012). Normative event segmentation, then, may serve as a proxy for real-world functioning in terms of both understanding of everyday events as well as enactment of everyday activities. Asking patients to engage in an event segmentation task may serve as one avenue by which clinicians can assess real-world functioning in a clinical setting. Moreover, event segmentation is subserved by a variety of cognitive faculties. Assessing event understanding may be one way to efficiently assess the overall cognitive status of a patient. Because the complaints of those presenting to the clinic often mirror the sorts of abilities that are being tested in an event segmentation task, the clinician may gain some insight into the nature of, and basis for, the complaint by utilizing ecologically valid tasks such as parsing of everyday activities. Specifically, evidence from the study by Bailey and colleagues (2013) suggests that segmentation scores specifically predict action omissions. Segmentation scores did not predict commission errors or action additions. In the home, this may translate to a patient missing important steps in pursuit of completing everyday activities. For example, a patient exhibiting poor segmentation scores in the clinic may miss adding toothpaste to the toothbrush before beginning to brush their teeth, or may fail to take one or more of their prescribed medications leading to incomplete medication adherence. Insights gleaned from the segmentation task extend beyond event perception to allow assessment of the patients' competence level in enacting instrumental activities of daily living (iADLs; Bailey et al., 2013).

Self- or caregiver-reported scales of the ability to perform iADLs, such as financial management or meal preparation are commonly used to quantify changes in everyday functioning (Argüelles, Loewenstein, Eisdorfer, & Argüelles, 2001; DeBettignies, Mahurin, & Pirozzolo, 1993). Many issues arise with the use of these measures, such as caregiver or patient bias. Moreover, the activities that are assessed vary from questionnaire to questionnaire leading to the potential for different conclusions to be drawn on the basis of the specific items included in the questionnaire. Possibly the most important limitation in patient-report iADL questionnaires is the fact that these rely on reports from individuals known to have cognitive impairment, often limiting the validity and reliability of these measures (Tabert et al., 2006). These measures lack sensitivity and have poor ecological validity (Gold, 2012). Moreover, iADLs are activities that are often cognitively more complex than basic activities of daily living, such as dressing and grooming and do not indicate the stage of enactment at which the breakdown occurs. For example, a poor rating for the medication management scale could stem from forgetting to take medications altogether, double-dosing on medications, mismanagement of medication timing or difficulty in suppressing environmental distractions such as a ringing telephone in order to complete medication administration. In other words, a poor rating on such an item does not give insight into the reason that the patient cannot manage medication.

The fact that existing questionnaire measures meant to assess iADL performance have poor reliability and validity has been well known for quite some time (see Gold, 2012). Why, then, are they still used? Questionnaire measures are still used, at least in part, due to the ease and cost-effectiveness of administration. Either the patient or a family member reports on the ability to carry out a variety of everyday activities in the form of a paper-and-pencil questionnaire. In many cases, the clinician has to do little more than provide the collateral with directions. This frees up the clinician's time during the patient's visit for other clinical tests and diagnostic measures. It is also not uncommon for these questionnaires to be mailed to the patient before the appointment or returned via mail from the patient or collateral from home. It would be relatively more time consuming and difficult for clinicians to ask patients to carry out everyday activities in either the patients' home or a clinical setting (Schmitter-Edgecombe, McAlister, & Weakley, 2012) in order to obtain a picture of the patients' level of everyday functioning.

Although performance-based assessments may seem like a superior alternative to questionnaire-based measures for understanding everyday functioning, there are limitations associated with performance-based assessments as well. First, training individuals to administer and score these types of assessments is time-consuming and costly. Second, specific components of the enacted activity may dominate observed performance level in a way that limits the ability to generalize observations from one particular enacted activity other everyday tasks. For example, medication management may require reading small print and it is unlikely that difficulties with that particular skill would give much insight into the patients' functional abilities in domains that do not require small-print reading, such as dressing or grooming. Another important limitation of performance-based measures is that when tasks are performed in the clinic, there is often much more structure and environmental support available to the patient in comparison to what they would experience in the home environment (Gold, 2012). The availability of such support might artificially boost performance of the task and could lead to an overestimation of the patient's functional status in everyday contexts.

Tasks tapping event segmentation and memory may occupy an attractive middle ground between paper-and-pencil measures and actual action performance tests such as the naturalistic action test (Schwartz, Buxbaum, Ferraro, Veramonti, & Segal, 2003; Schwartz, Segal, Veramonti, Ferraro, & Buxbaum, 2002). Event segmentation and memory indices provide a more detailed and ecologically valid measure of everyday functioning than paper-and-pencil tests, but require less time and expense than testing and scoring action performance itself. In the clinic, one might evaluate these abilities by asking patients to sit at a computer and segment videos of actors performing everyday activities, and then test their comprehension and memory. We view this as akin to employing a driving simulator to assess real-world driving safety (see also Gold, Park, Murphy, & Troyer, 2015; Gold, Park, Troyer, & Murphy, 2015).

With respect to memory specifically, event segmentation ability is known to predict memory for everyday events (Bailey et al., 2015; Zacks et al., 2006). Less is known about how event segmentation and event memory fare against traditional laboratory measures of memory such as list learning when it comes to predicting real-world memory functioning. One preliminary piece of evidence that event memory may predict real-world memory performance comes from a study by Bailey and colleagues (Bailey et al., 2015). In this study, having a genetic risk factor for Alzheimer's disease was associated with poorer performance on both tests of event memory and on traditional laboratory episodic memory measures. Importantly, memory performance was estimated more efficiently with the event-based tasks than with the laboratory tasks (25–30 min for encoding and memory testing for 3 movies compared to approximately 55–75 min for a three-task battery of traditional neuropsychological tests), and produced effects of similar magnitude. Moreover, memory-impaired participants may be less threatened or frustrated by the everyday event perception tasks than by laboratory memory tasks—watching a movie and describing it thereafter may be less aversive than attempting to memorize lists of words or pictures. Therefore, researchers and clinicians might consider pairing segmentation measures with traditional neuropsychological measures as well as questionnaire- or performance-based iADL assessments to provide a fuller picture of an individuals' level of everyday functioning and everyday memory.

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Event perception measures appear to be relatively uninfluenced by educational attainment, another important advantage over many neuropsychological measures. In the study conducted by Sargent and colleagues discussed above, education was found to be related to performance on laboratory tasks tapping working memory, episodic memory, processing speed and general knowledge, but no direct link was found between education and event segmentation or between education and event knowledge in a structural equation model. The only significant path from the laboratory measures to the event cognition metrics in the structural equation model was working memory to event segmentation scores. Importantly, only event segmentation and event knowledge directly predicted event memory (Sargent et al., 2013). When tested with linear regression, education did not significantly predict event memory. This provides evidence that event comprehension ability cannot be well understood by testing only on traditional laboratory or neuropsychological measures.

As technology continues to change at a fast pace, encouraging older adults in particular to learn new activities more efficiently on the first exposure and remember how to effectively carry out the activity later presents an important challenge with practical implications for maintenance of functional independence in old age. Training individuals to understand and parse events into smaller, manageable units may be one avenue to facilitate learning and memory for new activities as well as remediate performance of previously learned multi-step activities. We will now explore some methods that one could employ in pursuit of this goal, as well as the challenges facing researchers interested in pursuing work along these lines.

Approaches

There are at least two reasons to believe that improving event segmentation may facilitate performance of everyday activities: (1) better parsing of events is related to better memory for the event; and (2) better parsing of events is related to more efficient action execution. Training regimens targeting event segmentation are ecologically valid and would likely tap a range of cognitive faculties that underlie 'good' event perception. To give a hint as to the size of the effects in everyday memory performance one might expect from interventions targeting event segmentation, the magnitude of the relation between segmentation agreement and subsequent memory for the event in older adult samples in our studies range anywhere from $r = .26$ (Bailey et al., 2013) to $r = .57$ (Zacks et al., 2006); the relation between action enactment and event segmentation in the study by Bailey and colleagues was $r = .51$ (2013). Thus, there is potential for meaningful improvement in action execution and everyday memory following interventions targeting event segmentation.

To date, only a handful of interventions to improve event segmentation have been explored. Two studies have utilized a *think aloud* procedure in which participants describe an ongoing sequence of actions out loud as they watch the activity. A reasonable hypothesis is that because one needs to think about event structure in order to describe an activity, the think-aloud task will improve event segmentation. Consistent with this idea, the first study found that there was a greater degree of alignment between coarse and fine breakpoints when participants described the activity aloud compared to silently indicating breakpoints without verbal description (Zacks, Tversky, & Iyer, 2001). However, a subsequent study involving both younger and older adults failed to find a benefit of describing the ongoing activity for event memory in terms of both recall and recognition (Kurby & Zacks, 2011). More strikingly, the alignment effect found in the initial study was not replicated in this sample (Kurby & Zacks, 2011; Zacks, Tversky, & Iyer, 2001). Given these conflicting findings, it would be valuable to better characterize the situations in which talking about an activity helps and hinders effective event encoding. One possibility is that individual differences are important; for example, people with high working memory capacity might benefit from the think-aloud, but those with low working memory capacity might be hindered. Another possibility is that the nature of the materials is important; perhaps the think-aloud task will prove helpful for easily-described activities but less helpful for activities that are more difficult to verbalize, akin to the verbal overshadowing effect in episodic memory (Schooler & Engstler-Schooler, 1990).

A second intervention that has received stronger support as an intervention approach, involves using the event segmentation task to improve memory. In a series of 5 experiments conducted on Amazon Mechanical Turk, Flores and colleagues compared the standard segmentation task to pressing a button after a specific period of time had passed while the video was playing, and passively watching the video (Flores, Bailey, Eisenberg, & Zacks, in press). Participants in the segmentation condition were instructed to press a button whenever one natural and meaningful unit of activity ends and another begins (Newtson, 1973). When memory was tested immediately after encoding, performing the event segmentation task did not improve memory compared to the two control conditions (time-based button press and passive watching). However, when event memory was tested after a 10-min delay, the segmentation group exhibited better memory for the event in comparison to the two control conditions, and this effect held at delays up to one month. This indicates that effective encoding of event structure benefits memory over a timescale that is relevant in everyday life.

Recent work in our laboratory has explored the extent to which memory for everyday activities might be improved by drawing attention to event boundaries (Gold, Zacks, & Flores, submitted for publication). Younger and older adults viewed movies that were edited with cues to reinforce event structure: a tone, a slowing of the video, and (in one of the experiments) an arrow pointing to the object being acted upon. Cues were placed either at event boundaries or at event middles. For both older and younger adults, movies with cues at event boundaries were remembered better than unedited movies, indicating the cueing manipulation was effective. However, movies with cues at event midpoints also were remembered better than unedited movies, producing memory intermediate between the boundary-cued and unedited conditions. This suggests that features other than normative segmentation may have also contributed to the cueing benefit; one possibility is that simply being cued to pause and integrate from time to time facilitates event encoding.

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One approach to apply these principles to novel activity or skill learning is the Instructions Based on Event Segmentation (IBES) tool (Mura, Petersen, Huff, & Ghose, 2013). This computerized tool allows individuals to create instruction manuals for complex activities based on normative boundary points in the task. Individuals can create their own instructional materials based on how they parsed an activity at initial viewing. They can then write out instructions for each step and choose some still images to depict specific actions to be carried out during each step. Because the step-by-step instructions mirror those timepoints when boundaries have been identified (Mura et al., 2013), the relative match between event segmentation and instructions for enactment could be of great utility when learning a skill for the first time. In fact, the benefit of matching event segmentation and instructional materials has been observed previously (Zacks & Tversky, 2003); the IBES tool allows for the tailoring of instructional materials to individuals' own online perception. The IBES tool was recently introduced and it is not yet well understood how creating instructions with this method relative to standard instructional materials might improve learning and memory for activities, but this is an exciting and rich avenue for exploration. Possibilities include creating personalized instructions manuals for activities such as programming a cell phone, managing an electronic calendar, or even typical household chores such as emptying the dishwasher or setting the table in order to provide individuals struggling with completing iADLs independently another route to successful activity completion. Future iterations of the IBES tool may integrate some hierarchical structuring of instructional materials so that fine boundaries are represented as sub-parts of the larger coarse boundaries, as it has been previously shown that this sort of structuring can be particularly helpful when steps need to be completed in a specific order (Zacks & Tversky, 2003).

Other complementary approaches may prove to be beneficial for encouraging normative event segmentation. An approach that may prove to be fruitful involves capitalizing on implicit learning and implicit memory, because at least some implicit learning and implicit memory mechanisms are maintained in healthy aging (Fjell et al., 2009; Rieckmann & Bäckman, 2009) and in many neurodegenerative and psychiatric diseases affecting cognition; examples include medial temporal lobe amnesia (Schacter, Chiu, & Ochsner, 1993), schizophrenia (Clare, McKenna, Mortimer, & Baddeley, 1993), and Alzheimer's disease (Randolph, Tierney, & Chase, 1995). Because everyday events have structure (Newtson, 1976), and individuals spontaneously parse events according to this structure outside of explicit awareness (Zacks, Braver, et al., 2001), cueing individuals to normative event boundaries by providing implicit cues may lead to larger training benefits than have previously been observed. Specifically, inserting small imperceptible changes, such as slowing the frame rate around normative boundary points may prove to be a useful way to cue individuals to the widely agreed-upon placement for event boundaries. In the Gold, Zacks, and Flores study described previously, the use of momentary slowing of the video may well have acted through implicit memory mechanisms as well as explicit ones.

Promise and Challenges

Although there are some challenging aspects to this type of work, improving everyday event perception and thereby event memory and enactment of activities has important implications for researchers and clinicians. Event comprehension is potentially relevant to occupational and physical therapists working in rehabilitation settings, medical professionals in treatment and diagnostic centers, and basic cognitive scientists interested in rehabilitation. Individuals creating interventions targeting remediation or improvement of abilities in everyday cognition could benefit from incorporating more ecologically valid tasks into traditional methods used in their respective fields. Because the abilities that can be tapped by event perception are broad and the potential for improving event perception is not only clinically relevant but also important to maintenance of independent living, this approach could serve to augment extant methods in both initial assessment and as a marker for improvement.

As exciting as the potential for this work is, challenges to carrying out these types of interventions remain. For one thing, we do not yet know how malleable segmentation ability is. There is evidence that individual differences in segmentation are to some degree consistent over time (Speer, Swallow, & Zacks, 2003) but we do not yet know to what extent we can change someone's segmentation with training. If event segmentation interventions implemented in healthy individuals do not produce major improvements in this ability, it is still possible that decrements in event segmentation due to injury or disease could be remediated by intervention. A good analogy is gait: under normal circumstances individual differences in gait are highly stable, but when gait is perturbed by physical or neurological injury, therapy can be highly effective in restoring function. Thus, it is possible that interventions will be more useful in individuals exhibiting difficulty with normative event segmentation than in individuals who are already displaying segmentation ability in the normal to high end of the range.

Even if effective therapies to restore event segmentation ability prove elusive, it may be possible to compensate for segmentation impairments with appropriate training or cognitive aids. In the rehabilitation setting, we can distinguish between *rehabilitation*, or increase of function, and *remediation*, defined by the use of adaptive tools or strategies that serve as 'crutches' to offer extra support for lost functionality (Abreu & Toglia, 1987). Even if the ability to perceive events in a normative fashion proves difficult to rehabilitate, there may still be strategies and environmental supports that could be of use to those with impoverished event segmentation. One example of this might be the cueing paradigm described above (Gold et al., submitted for publication). Individuals who experience these normative boundary points via external cues might understand that things such as change in sub-goal, larger motor movements, and change in objects interacted with, are related to these normative breakpoints. These individuals could then use this strategy to identify those boundary points that are normative even in the absence of the subjective prediction error spike and related processes that underlie boundary identification for others.

Importantly, little is known about the developmental trajectory of event segmentation. If it is found that there is little malleability in this cognitive skill in adults, then early intervention programs may prove to be more efficacious (see Zalla, Labruyère, & Georgieff, 2013 for an example of clinical developmental work in event segmentation). Unfortunately, to design any intervention program of this nature, researchers would need a much better understanding of what typical event segmentation looks like across childhood and adolescence. There is a relatively better understanding of the development of neural substrates that support event segmentation and normative boundary identification (Kurby & Zacks, 2008, Box 3). In fact, there is some preliminary evidence that even infants are sensitive to these normative breakpoints in events. When videos were paused prior to an actor completing his goal, infants looked longer at these timepoints compared to after goal completion (Baldwin, Baird, Saylor, & Clark, 2001; for a review see chapter 10, Radvansky & Zacks, 2014). A study in older children with autism-spectrum disorder, children with moderate learning disabilities or intellectual disability and typically developing controls found that both clinical groups were impaired on identifying normative event boundaries at the coarse level, but only the autism-spectrum group was impaired at the fine-grained level (Zalla et al., 2013). Aside from the interesting clinical implications of this study, it also demonstrates that normally developing children are able to identify normative event boundaries at both the coarse and fine-grained level. Early interventions for clinical populations known to have difficulty with normative event segmentation, or other related functional targets such as social processing or theory of mind abilities, may have an impact on the ability to parse events in a normative fashion.

As has been the case in many other fields, it can be difficult to select the task or tasks that will be used to demonstrate improvement beyond the training setting (see Morrison & Chein, 2011 for a discussion of this issue in the cognitive training literature). It is especially difficult to compare the effectiveness of intervention strategies when different tasks are being utilized to demonstrate improvement. For interventions targeting event segmentation, this issue is especially salient because the goal is functional improvement in everyday life, but, it may be unrealistic or difficult to demonstrate such an improvement. It is possible that lab-based proxies for everyday functioning such as the naturalistic action test (Schwartz et al., 2002) or virtual reality scenarios (Cipresso, Matic, Giakoumis, & Ostrovsky, 2015) may provide important insight on this front. Because these are exactly the kinds of skills that individuals who engage in cognitive training care about being able to execute, demonstrations of improvement in parsing, remembering or enacting events would represent quite meaningful training benefits. Moreover, the ability to 'transfer' skills training (i.e., parsing events) to test conditions (enacting activities in the real world) represents a nearer form of transfer compared to previously utilized intervention strategies.

Many of the cognitive processes underlying normative event segmentation, including maintaining and updating an event model, making predictions, and monitoring prediction error, present targets in and of themselves for improving performance. While it may be difficult to design an intervention that targets not only event segmentation itself, but also the cognitive processes essential for normative event segmentation, this type of combined approach may be able to produce larger benefits in event-based metrics. If interventions targeted specifically toward improving event segmentation do not have a large impact on this ability, these other abilities offer alternative potential avenues for therapeutic targeting. In addition, training these cognitive abilities in conjunction with targeted interventions aimed at event segmentation may prove to be a fruitful path. Researchers interested in working with clinical populations especially may want to consider such a multi-modal approach to tackle both more general cognitive difficulties as well as event segmentation specifically in order to maximize the effects of both intervention strategies.

This will not be an easy road. Interventions that may work for healthy older adults or children may not work in clinical samples and vice versa. The length of training needed to see functional improvements and the skills impacted may differ at both the level of group differences and at the level of individual participants. The ultimate goal of any intervention study is to understand the conditions under which a particular intervention might be most beneficial for a particular cognitive profile. However, there is much to be gained if effective interventions are discovered. The importance and potential impact of identifying effective strategies to improve event segmentation and the related abilities of action control and event memory should serve to propel this line of work forward.

Conflict of Interest Statement

The authors declare no conflict of interest.

Author Contributions

Lauren L. Richmond and David A. Gold drafted an outline of the paper. Jeffrey M. Zacks offered comments and suggestions on the outline. Lauren L. Richmond wrote the intial draft. Lauren L. Richmond, David A. Gold and Jeffrey M. Zacks wrote subsequent drafts of the manuscript.

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