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CHANGE DETECTION AS A TOOL FOR ASSESSING ATTENTIONAL DEPLOYMENT IN ATYPICAL POPULATIONS: THE CASE OF WILLIAMS SYNDROME

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ABSTRACT

When unexpected changes occur in a visual scene, people often fail to notice them. Because change detection depends on attentional mechanisms, people tend to notice changes that are of special significance. People with Williams syndrome (WMS) have an unusually strong interest in other people that is manifest in relatively spared face recognition skills, heightened social attention and hypersociability. We hypothesized that in a change blindness paradigm participants with WMS would be more sensitive to changes in people in social scenes compared to age, IQ and language matched participants with learning or intellectual disabilities. Two videos were presented, one showing an unexpected change to the identity of an actor and one with numerous unexpected changes during a conversation scene. Subjects in both the WMS and the learning disabilities groups noticed fewer overall changes than age-matched normal controls, suggesting that change detection is especially challenging to people with intellectual disabilities. Consistent with our hypothesis, WMS subjects noticed more person-related changes in the complex scene than did subjects with other intellectual/learning disabilities. WMS subjects attend to social elements of dynamic scenes, decreasing change blindness for changes associated with people.

KEYWORDS*: *Williams syndrome, change detection, change blindness, attentional biases.

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INTRODUCTION

How people encode their visual environment depends to a large extent on how attention is deployed in real-time. Although our perceptual experience seems rich in detail, people are surprisingly poor at noticing large changes to visual scenes if the changes occur during a visual disruption, and this “change blindness” is accentuated when the changes are unexpected (see Rensink, 2002; Simons & Ambinder, 2005 for recent reviews). For example, nearly two-thirds of observers failed to notice when the only actor in a brief motion picture was unexpectedly replaced by a different actor during a cut from one shot to the next (Levin & Simons, 1997). Change detection is enhanced when the change occurs instantly, producing a visible transient signal (Rensink, O’Regan, & Clark, 1997). However, change blindness ensues when the perceptibility of the transient signal is disrupted by a blank screen (e.g., Rensink et al., 1997), an eye movement (e.g., Grimes, 1996; Henderson & Hollingworth, 1999; McConkie & Currie, 1996), a blink (O’Regan, Deubel, Clark, & Rensink, 2000), or a cut or pan in a motion picture (e.g., Simons & Levin, 1998; Levin & Simons, 1997). This pervasive change blindness occurs both when observers intentionally search for change and when changes occur unexpectedly.

Evidence from a variety of paradigms suggests that attention to the change is necessary for change detection. Observers must encode the pre-change scene and compare it to the post-change scene, a seemingly attention-demanding process. To the extent that attention is needed for change detection, successful change detection implies that the changing element was attended and encoded (Tse, 2004). In support of this assumption, changes to objects rated as more important to the scene are noticed more readily than less important objects (Rensink et al., 1997). Several studies have relied on this assumption, using change detection tasks to measure the capacity of attention (Rensink, 2000) and to map the spatial locus of attention (Tse, Sheinberg, & Logothetis, 2003; Tse, 2004). Individual and group differences in expectations, interest, and expertise also influence the focus of attention in scenes, leading to enhanced or impoverished change detection performance. For example, recreational drug users and problem drinkers are more likely than non-users to notice changes to drug paraphernalia and alcohol-related items, respectively (Jones, Jones, Smith, & Copley, 2003; Jones, Bruce, Livingstone, & Reed, 2006). Japanese subjects are more likely to notice changes to the context in a scene whereas American subjects are more likely to notice changes to the central objects (Nisbett & Masuda, 2003).

In this study we investigated change detection in participants with Williams syndrome and a comparison group matched on age, IQ, and language ability. Williams syndrome (WMS) is a neurodevelopmental disorder caused by a microdeletion spanning approximately 1.6Mb on the long arm of chromosome 7 (7q11.23), a region encompassing about 25 genes including the gene encoding elastin (Osborne, 2006). This genetic deletion is associated with particular physical features (Morris, 2006), and with a striking and unique behavioral and cognitive profile that has sparked the interest of cognitive neuroscientists (Bellugi & St. George, 2000; Meyer-Lindenberg et al., 2004). Despite mild to moderate levels of mental retardation and extremely impaired visuospatial construction skills, people with Williams syndrome have relatively rich vocabularies, verbal fluency, proficient face recognition, and a remarkably strong propensity for social engagement (Tager-Flusberg & Plesa Skwerer, 2006). Children and adults with WMS are friendly, outgoing, and score high on measures of empathy and sociability (Klein-Tasman & Mervis, 2003). This strong social interest is evident in infants and young children with WMS who attend for lengthy periods of time and with unusual intensity to people (Jones et al., 2000; Mervis et al., 2003). Social attention has not, however, been investigated in older children or adults with WMS. Moreover, most studies of social attention in WMS have not explored attention to complex, dynamic visual scenes.

We presented two change detection tasks to determine whether adolescents and adults with WMS show heightened attention to social elements of scenes. In the first, there was a change in the central character in a brief video; in the second there were numerous changes that took place during a conversation between two people, some related to the objects in the scene and others related to the people engaged in the conversation. Given the attentional demands of the task, we expected that overall both groups would notice fewer changes than age-matched typically developing controls (cf. Bergen & Mosely, 1994; Schweizer, Moosbrugger, & Goldhammer, 2005). We hypothesized that the WMS subjects would be more likely than the matched comparison group with learning/intellectual disabilities to detect person-related changes in the second video, indicating their disproportionate attention to people in a complex scene.

METHOD

Participants

Three groups of adolescent and adult participants (aged 12 to 35 years) were included in this study: 46 with WMS, 46 with learning or intellectual disabilities (LID) and 67 normal controls (NC). WMS participants were recruited through the Williams Syndrome Association. All WMS diagnoses were confirmed by a clinical geneticist or genetic testing (FISH test – fluorescence in situ hybridization). The LID group, group-matched on age, IQ and language with the WMS group, included a mixed-etiologies sample of participants with learning or intellectual disabilities recruited through a residential school serving this population, none of whom scored highly for autism symptoms on the Social Responsiveness Scale (Constantino, 2004). Normal control participants were recruited from local schools and universities and were matched to the clinical subjects on chronological age, $F\ (2, 156) = 0.94$, $p = .39$.

All participants completed the Kaufman Brief Intelligence Test (KBIT; Kaufman & Kaufman, 1990) to assess IQ and the Peabody Picture Vocabulary Test-III (PPVT-III; Dunn & Dunn, 1997) to assess verbal knowledge. As expected (see Table 1a), the three groups differed in IQ, F (2, 156) = 202.61, $p < .001$ and verbal knowledge, F (2, 156) = 79.99, $p < .001$. The clinical groups were well matched on these measures, having comparable IQs ($p = .79$) and verbal knowledge scores ($p = .59$), but both groups scored significantly lower than the NC group ($p < .001$) on both measures (by Scheffé post-hoc comparisons).

Table 1a.
Task 1: Means (and Standard Deviations) for Participant Characteristics

	Williams Syndrome (N = 46)	Learning Disabled (N = 46)	Normal Controls (N = 67)
Chronological age	19;3 (6;5)	17;11 (3;1)	19;6 (6;5)
Full Scale IQ (KBIT)	68.6 (11.4)	70.0 (11.7)	102.6 (8.4)
Vocabulary (PPVT-III)	79.8 (8.9)	82.4 (11.4)	105.9 (14.6)

Change Blindness Tasks

Task 1. Person-change

This silent video involved a change to the identity of the only character in an approximately 8 seconds long motion picture depicting a simple action sequence (the video was from research by Levin & Simons, 1997). In the video, a woman sitting at a desk in the center of the screen looks up in the direction of the camera, stands, and walks toward the camera. As she exits the room the camera cuts to a shot of the hallway and a different woman enters the hallway and answers a telephone on the wall (Appendix A). The original film was edited so that the motion sequence was consistent with a single actor. The two women in the film were both Caucasian, had similar hair color, and wore similar clothing. In a second version of the film, the two actresses swapped roles, and each version was viewed by approximately half of the participants in each group.

Participants viewed the video on a 15” Dell laptop computer screen during a break from other experiments conducted during the same testing session. They were invited to watch the video and try to pay attention because it is a very short movie. After viewing, they were asked: “Tell me what did you see, what happened in this movie?” If they did not mention any changes, they were asked the first probe question: “Did you notice anything unusual about the person in the video?” If they still failed to mention any changes, they were asked the second probe question: “Was it the same person who was sitting at the desk and then answered the phone in the hallway?” All responses were audiotaped, and the recordings were transcribed verbatim. Responses were coded as 1 if the participant clearly noticed the change in person, either by spontaneously mentioning it when instructed to describe what happened in the movie, or by referring to the change in the *identity* of the actors after the 1st probe question. Responses such as "her hair color and clothing changed" without specifying the change in identity were considered ambiguous and not scored. Similarly, those who seemed to change their answer after the 2nd probe (e.g., saying that they did notice that it was a different person, even though they had not mentioned it in describing the video or in response to the 1st probe question) were also considered ambiguous and not scored. Responses were scored 0 if the participant did not mention the person change after being asked the probe questions. This stringent system of scoring responses led to eliminating from data analyses 14 participants from the NC group, 3 from the WS group and 2 from the LID group for having given ambiguous answers that were not scored 1 or 0.

Task 2. Conversation

In a subsequent experimental session, most of the participants described above (44 WMS subjects, 33 LID subjects, and 51 control subjects) viewed a second more complex video of a conversation between two actresses seated at a table where food had been served (see Appendix B; also from Levin & Simons, 1997). Although not all of the individuals who watched the Person Change video were able to participate in the second experimental session, the three groups that were administered Task 2 remained well matched on age, $F(2,125) = .48$, $p = .62$, and the LID and WMS groups were also matched on IQ ($p = .89$) and verbal knowledge ($p = .64$, by Scheffé comparisons). Table 1b presents details of the participant groups for Task 2.

Table 1 b
Task 2: Means (and Standard Deviations) for Participant Characteristics

	Williams Syndrome (N = 44)	Learning Disabled (N = 33)	Normal Controls (N = 51)
Chronological age	19;0 (6;6)	17;11 (3;4)	19;1 (6;0)
Full Scale IQ (KBIT)	68.3 (11.5)	69.4 (12.1)	103.8 (8.3)
Vocabulary (PPVT-III)	79.7 (8.9)	82.2 (12.5)	106.7 (14.2)

The 'Conversation' video was 35 seconds long and started by showing a shot of both actresses followed by a sequence of shots of each actress individually as they spoke or listened. During every cut, at least one change occurred to the objects on the table, the body positions of the actresses, or the clothing, for a total of 9 defined changes (See Table 2). Participants were asked to "pay close attention" to the video, but were not forewarned of the changes. After viewing, they were asked: "Did you notice anything unusual in the video, or see any unexpected changes from one shot to the next?" After answering this question they were told that several changes involving objects, clothing, and the way the actresses sat had occurred. The video was presented two more times and after each viewing participants were asked to identify as many changes as possible. All responses were audiotaped and then transcribed. The total number of actual changes (see Table 2 for list) mentioned across all three viewings constituted the dependent variable of interest for statistical analyses. Changes mentioned by each participant were coded online and confirmed using the transcripts.

Table 2
Defined Changes on the Conversation Video

Scene Order	Changes	Number of changes
Scene 2	Actor A is no longer wearing *the scarf* visible in the first scene	1
Scene 3	A's *scarf* has returned and B's *hand* is now on her chin, not on the table	2
Scene 4	The *plates* on the table are now *white*, not red, and B's *arms* are crossed with elbows resting on the table	2
Scene 5	The *plates* are *red* again, and A's *hand* now rests on her lap, not on the table.	2
Scene 6	The *food, cup, and utensils* on A's place setting have switched with those on B's place setting, and A's *right hand* again rests on the table	2

The transcripts were also coded for comments that were unrelated to the defined changes but that referenced the characters' emotional state (e.g., "first she was happy, happy her friend came… then they were angry because of the traffic"), their appearance (e.g., "this lady is short, she is looking a different way"); or their dialogue (e.g., "they were talking about the train station, how long it takes"). Two coders unaware of participant group membership were instructed to identify all references to the characters' emotional states, appearance, or dialogue that were not valid changes. Reliability was calculated on a random sample of 25 transcripts from all subject groups and was over 95% for all three types of references. The remaining transcripts were divided between the two coders and scored blind to group. Three audio recordings (2 from the NC subjects and 1 LID subject) were unintelligible, so the data from these 3 participants were not included in this analysis, although their data were included in the change detection analyses.

RESULTS

1. Person Change

Consistent with the original experiments with person-change videos (Levin & Simons, 1997), 39.6 % of the NC subjects clearly detected the change of person (see Table 3).

Table 3
Number (and Percentage) of Participants Who Noticed the Person Change – Task 1

	Williams Syndrome (N = 43)	Learning Disabled (N = 44)	Normal Controls (N = 53)
Did not see change	36 (83.7)	40 (90.9)	32 (60.4)
Definitely saw change	7 (16.3)	4 (9.1)	21 (39.6)

Detection rates were lower for WMS subjects (16.3%) and LID subjects (9.1%), χ^2 (2, N =140) = 14.32, p < .001. Follow up tests showed that the NC group outperformed the WMS subjects, χ^2 (1, N = 96) = 5.18, p = .023 and the LID subjects, χ^2 (1, N =97) = 10.18, p = .001, but the difference between the WMS and LID subjects was not significant, χ^2 (1, N = 87) = .47, p = .49. Given that the social elements of this video (i.e., the actress) was the center of interest, it is not surprising that WMS subjects and LID subjects performed comparably; both likely focused attention on the actress, leading to comparable rates of detection. This finding suggests that these groups were equally likely to detect unexpected changes to a central attended object in a motion picture.

2. Conversation

Unlike the person-change video, the changes in the conversation film were largely tangential to the content of the film. However, as can be seen in Table 2, some of these changes were to social elements of the scene related to the people in the video (e.g., the body positions and clothing) while others were to non-social elements related to the objects in the scene (e.g., the color of the plates). Consistent with the original study using this video (Levin & Simons, 1997), most participants failed to notice any changes during the first viewing; three WMS participants (7%), 1 LID participant (3%), and 13 NC participants (25.5%) noticed at least one unexpected change during the first viewing. As with the person-change video, the NC group noticed more changes than the clinical groups, χ^2 (2, N =128) = 12.79,

$p < .01$, and the two clinical groups performed comparably, χ^2 (1, N =77) = .549, $p = .459$.

In the original studies, subjects still noticed few changes when viewing the video a second time and explicitly looked for changes (Levin & Simons, 1997). Our subjects viewed the video two more times after the first viewing. Combining across these three viewings, the groups again differed in the total number of changes noticed, χ^2 (2, N =128) = 54.88, $p < .0001$, with the NC group noticing more changes across the three viewings than did the other two groups (NC: M = 3.33; WMS: M = 1.16; LID: M = .73). The WMS subjects noticed significantly more changes than the LID subjects, χ^2 (1, N =77) = 6.11, $p < .02$. Only one LID participant detected more than 2 changes across multiple viewings, but 14 WMS participants noticed 2 or more changes (5 WMS subjects detected a total of 3 changes, and 1 detected 4 changes).

We predicted that WMS subjects would focus on social aspects of the scene, leading to better detection of changes to the people or their appearance. To determine whether better change detection by WMS subjects than LID subjects resulted from greater detection of changes to social scene elements, we examined detection of person- and object-related changes separately for these two groups. Significantly more WMS subjects (52.3%) than LID subjects (27.3%) detected person-related changes, χ^2 (1, N =77) = 4.85, $p < .03$, however the WMS and LID subjects performed comparably for object-related changes,χ^2 (1, N =77) = 0.18, $p = .89$ 40.9% of the WMS and 39.4% of the LID). Thus, better overall detection by WMS subjects appears to result from better detection of person-related changes, suggesting that they had focused attention on social aspects of the scene.

Participants often commented on aspects of the video that were not among the 9 defined changes (see Figure 3). Consistent with the idea that WMS subjects focus on social elements of a scene, proportionally more of the WMS subjects (43.2%) than the LID (12.5%) and NC subjects (12%) commented on the emotional states of the characters, χ^2 (2, N=126) = 15.52, $p < .001$. Moreover, almost all NC subjects (94%) and 91% of WMS subjects, but only 59.4% of LID subjects referenced the appearance of the actors, χ^2 (2, N=126) = 19.85, $p < .001$.

Spearman correlations were computed to examine relations between cognitive abilities and change detection rates in the two tasks for each group. For both the clinical groups, IQ and change detection in the conversation task were significantly correlated (WMS: r_s (43) = .32, $p < .05$; LID: r_s (33) = .50, $p < .01$. Correlations between change detection rates and age were not significant in any group (r_s (44) = .073, $p = .64$ for the WMS group, r_s (33) = .025, $p = .16$ for the LID group and r_s (51) = .085, $p = .55$ for the NC group).

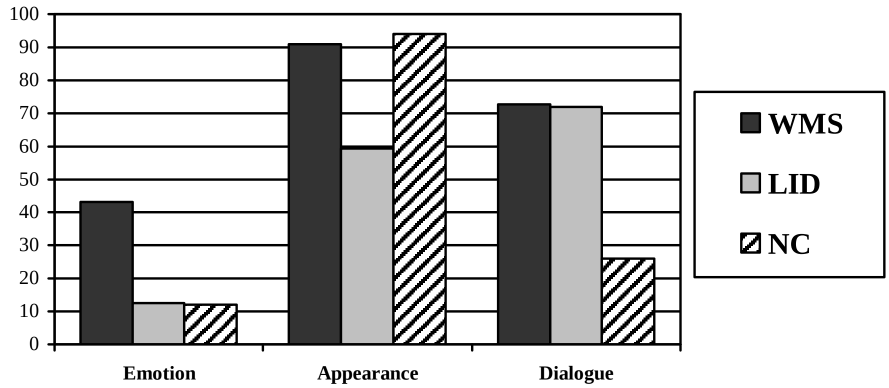

Figure 3. Percentage of participants commenting on unintended changes in the conversation video.

DISCUSSION

This study used change detection as a method for exploring attention to scenes in adolescents and adults with neurodevelopmental disorders, in particular, Williams syndrome. The main findings were that overall, people with disabilities are significantly less likely to notice changes in both simple and complex scenes than are age-matched typical controls. Indeed, for both clinical groups, performance on change detection tasks was significantly correlated with IQ (but not age). We also found that relative to a comparison group matched for age, IQ, and language, subjects with WMS were significantly more likely to notice changes to social elements and were also more likely to comment on the appearance of the actors and their emotional states in the conversation video, indicating that they were biased to focus their attention on social elements of complex, dynamic scenes.

People with WMS tend to have disproportionate social interest and social motivation relative to other clinical populations. Change detection tasks provide a useful way to measure the locus of attention, and they have been used to reveal other group differences in attentional preferences based on motivational factors (Nisbett & Masuda, 2003; Jones et al, 2003; Jones et al, 2006; Werner & Thies, 2000). Given that successful change detection appears to require an attentive comparison of the pre- and post-change information (Mitroff & Simons, 2004; Scott-Brown, Baker, & Orbach, 2000; Simons & Rensink, 2005), better change detection for some items than others suggests an attentional bias to focus on those items. Thus, differences in susceptibility to change blindness relative to different types of changes may provide a method for exploring the role of motivation or cognitive biases in prioritizing which aspects of the environment are spontaneously attended to rather than simply a method for evaluating the efficiency of attention deployment. One recent study reported on the use of change detection paradigms to investigate attentional biases in people with autism using scenes that only included non-social objects (Fletcher-Watson, Leekam, Turner, & Moxon, 2006). The main findings were that adolescents and young adults with autism did not show an atypical bias toward noticing marginal, non-central items in a visual scene and were also as likely as controls to notice changes in contextually inappropriate objects. It would be interesting to follow up these findings to investigate whether people with autism would show significantly greater bias toward attending to the *non-social* elements of a scene when both social and non-social elements are present (cf. Klin, Jones, Schultz, Volkmar, & Cohen, 2002).

Both clinical groups in our experiment detected fewer changes in each video than did the control subjects, and the LID and WMS subjects did not differ in their detection of the person change, which was the central element in a relatively simple scene. The poor performance by the participants in the clinical groups in the first task may be related to the brevity of the video, the presence of only a single change, the lack of explicit instructions to identify changes, or the lack of experience with movie cuts. In the conversation video the scene was more complex and included a variety of different elements, allowing more opportunity for attention biases to influence change detection performance. Furthermore, the video was repeated three times and included explicit instructions to identify changes. For that video, a higher proportion of WMS subjects noticed more person-related changes than did the matched LID subjects. These findings suggest that people with WMS are more attuned to people in their environment than are people with other disabilities, complementing conclusions from studies of infants and young children with WMS that used different methodologies (Laing et al., 2002; Mervis et al., 2003). Consistent with this conclusion, WMS subjects were more likely than LID subjects to mention putative changes in the appearance of the characters or to comment on their emotional states. These findings provide empirical support for anecdotal observations about people with WMS. Interestingly, almost half the WMS subjects described the characters' emotions even though the actresses' facial expressions were essentially neutral throughout the video. Thus, our results do not necessarily reflect better perception of facial expressions; indeed children and adults with WMS are poorer than age-matched controls in labeling facial expressions (Gagliardi et al., 2003; Plesa Skwerer, Faja, Schofield, Verbalis, & Tager-Flusberg, 2006; Tager-Flusberg & Sullivan, 2000).

Despite their relatively greater sensitivity to person-related changes, WMS subjects performed significantly worse than age-matched typical controls suggesting that the hypersocial profile of WMS does not translate into enhanced detection of person change when compared to normal controls. Overall, the WMS group performed comparably to a group of learning disabled and mentally-retarded adolescents and adults who were well matched on age, language, and IQ. The difference between the clinical groups and the normal control group as well as the significant relationship between IQ and change detection for both clinical groups suggests that IQ influences some aspects of change detection performance. This finding is consistent with other research suggesting a link between intelligence and a variety of attentional variables including attentional switching, spatial attention and sustained attention (Schweizer et al., 2005; Weyandt, Mitzlaff, & Thomas, 2002). Moreover, many people with neurodevelopmental disorders including WMS have documented problems with distractibility and an inability to concentrate on a task which may also have affected their performance (Dilts, Morris, & Leonard, 1990). Whether better performance of higher-IQ participants reflects superior visual encoding of the scene, greater attentional breadth in focusing on multiple objects, better memory for scene elements, or increased capacity to compare elements before and after a change remains to be determined. Systematic studies of individual differences are surprisingly lacking in the change detection literature (although see Pringle, Irwin, Kramer, & Atchley, 2001). The relationship between performance on a deceptively simple task such as visual change detection and individual differences in IQ highlights the importance of including control groups carefully matched on both age and intelligence when studying WMS. Most studies of WMS have failed to include appropriately matched groups, leading to conflicting findings and interpretations that could have more to do with developmental level and mental retardation than with the unique abilities of people with WMS (Tager-Flusberg, 2004).

Several studies have used functional imaging methods to investigate which areas of the brain are activated during change blindness tasks. Detection involving the conscious awareness of changes in visual scenes depends on a coordinated distributed neural network that includes parietal and dorsolateral prefrontal cortical areas that are involved in controlling the deployment of attention to the locus of change, allowing for further processing of the visual stimulus (Beck, Rees, Frith, & Lavie, 2001; Huettel, Guzeldere, & McCarthy, 2001; Pessoa & Ungerleider, 2004). Prefrontal cortex is associated with individual variation in general intelligence as well as executive processes that are known to be impaired in people with neurodevelopmental disorders (Gray & Thompson, 2004; Kane & Engle, 2002). Moreover, tasks that demand attentional control that are significantly related to fluid intelligence measures activate both lateral prefrontal and parietal regions, and seem to depend on integration across these distributed brain regions (Gray, Chabris, & Braver, 2003). We suggest that the relatively poor performance of the WMS and LID groups on our change detection task is related to impairments in prefrontal regions, and their connectivity with parietal cortex.

The WMS participants were more likely than the LID participants to identify changes related to the social elements in the conversation video and to describe the emotional states of the actors, indicating that their attentional focus was on the people rather than on the nonsocial areas of the visual scene. An interesting next step would be to use eye-tracking methods to determine whether gaze patterns are similarly affected by such group differences in attentional biases (Chua, Boland, & Nisbett, 2005). The atypical attention to social aspects of their world found in the WMS group in our study may be driven by affective or motivational factors that have yet to be elucidated. Future research should address the neurobiological basis of this attentional bias, perhaps linking it to specific genes within the critical region that is deleted in WMS.

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Appendix A

Central Person Change Video

Appendix B

Two Scenes from the Conversation Video (plates changed color from one scene to the next)