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Original Research Article

Measuring Electrodermal Activity to Improve the Identification of Agitation in Individuals with Dementia

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Keywords

Dementia · Electrodermal activity · Agitation · Behavioral psychological symptoms in dementia

Abstract

Background: Understanding and interpreting the complexity of agitation in people with dementia is challenging. ***Objective:*** To explore whether a sensor measuring electrodermal activity (EDA) can improve the identification of agitation in individuals with dementia. ***Methods:*** Nine individuals with dementia wore a sensor that measured EDA. During the same time, assistant nurses annotated the observed behavior of the person with dementia. A binary logistic regression model was applied to assess the relationship between the sensor and the assistant nurses' structured observations of agitation. ***Results:*** The sensor values correlated with the assistant nurses' observations both at the time of the observation and 1 and 2 h prior to the observation. ***Conclusion:*** A sensor measuring EDA can support early detection of agitation in persons with dementia.

Introduction

Agitation is a common behavioral and psychological symptom in people with dementia and is often seen as a reaction to emotional, environmental, or physiological stress. To prevent the onset of agitation, it is essential to adequately assess and monitor behavioral patterns. This allows nursing staff to target triggering factors with effective care interventions [1]. There are indications that information about behavioral patterns can be gathered by monitoring stress [2] with measurements of electrodermal activity (EDA) [3]. To monitor and interpret the

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moods and behaviors of individuals with dementia is often challenging for nursing staff, and using sensors to measure EDA can be a valuable tool to enhance the accuracy of assessments. Sharma et al. [4] state that measuring EDA may aid monitoring of the individual's emotional experiences and support the identification of and response to his or her needs.

Agitation has been viewed as an expression of needs and feelings and a response to internal or external stimuli [5]. Agitation as a reaction to different kinds of stress can have a negative impact on the health and well-being of the person with dementia as well as caregivers [6]. Kessler et al. [7] define stress as a process in which internal or external demands exceed a person's adaptive capacity, resulting in psychological and physiological changes that may increase the risk of diseases. Agitation in dementia can be defined as excessive, inappropriate, repetitive, nonspecific, and observable motor or verbal activity [5] and includes a variety of different behaviors, such as hitting, wandering, general restlessness, constant demands for attention and reassurance, complaining, or hoarding [8]. Furthermore, agitation is persistent during the course of the dementia disease [9, 10] and is associated with decreased quality of life [11] and inappropriate use of psychotropic drugs [12].

Stress is known to activate the sympathetic nervous system (SNS) and can be detected with physiological parameters influenced by the SNS, such as muscle activity, heart rate, EDA, and pupil diameter [13]. A change in SNS activity results in a slight increase in perspiration, which lowers skin resistance since perspiration contains water and electrolytes. These changes in the skin's electrical resistance are recorded between two electrodes placed on the skin. EDA appears following stimulation that produces emotional reactions or aroused alertness and is considered a useful measurement for indicating stress [4]. For example, EDA has been used to detect aggressive behavior, as it increases sharply before the first signs of aggressive behavior are visible [14]. It has also been used to measure mood change in older people [15] and to investigate people with dementia who are faced with moral dilemmas and their reactions [16].

Since people with advanced dementia face challenges in communicating their needs and subjective well-being, the interpretation of these is, to a large extent, based on behavioral and nonverbal aspects [1]. Understanding and interpreting the complexity of agitation is difficult, and nursing staff need support in assessment and monitoring. Part of the complexity of assessing and monitoring agitation is that staff may lack the required skills to perform sophisticated observations, and the interpretation of observed behavior may be influenced by the level of distress that the symptom causes [17, 18]. In addition, the time available for observation may be brief and interactions few since nursing staff are not present at all times and may also perceive behaviors differently. To support nursing staff in identifying and understanding the complexity of agitation, various structured assessment tools have been developed [19], but most are based on observational data requiring close proximity between staff and the individual with dementia over a substantial period, which can be challenging to attain.

The aim of this study was to explore whether a sensor measuring EDA can improve the identification of agitation in individuals with dementia. Specifically, the hypotheses were that there is a relationship between the assistant nurses' observations of agitation and an increase in EDA detected by the sensor; and that the sensor indicates an increase in EDA prior to assistant nurses' structured observations of agitation.

Materials and Methods

Study Design

This study was a nonexperimental and correlational observation of the relationship between a sensor measuring EDA and assistant nurses' structured observations of agitation in individuals with advanced dementia.

Participants and Setting

Nine individuals residing in four different dementia care units in northern Sweden were purposefully selected based on consultation with experienced key informants consisting of unit managers and nursing staff at the dementia care units. The criteria for residents' participation were a diagnosis of dementia and having demonstrated problematic behaviors according to the Neuropsychiatric Inventory-Nursing Home version [20, 21] at the time of inclusion. The dementia care units had common areas and apartments for ten residents; the nursing staff comprised trained assistant nurses experienced in assessing and supporting people with dementia.

Ethical Considerations

The study was approved by a Regional Ethical Review Board for research, No. 2013/10-31. The use of sensors may pose a risk of intrusion into the personal sphere [22] and may affect the integrity of persons with dementia due to, among other factors, difficulties obtaining informed consent. Therefore, providing information to relatives and staff who knew each participant well was important. A double-consent procedure was used: the assistant nurses continuously evaluated participants for signs that they no longer wished to participate, for example, by refusing to wear the sensor, as well as informing and receiving consent from a proxy [23]. The assistant nurses were given verbal and written information about the study at a common meeting. All data were de-identified and processed confidentially [24].

Data Collection

Sensor. The sensor used was the Discrete Tension Indicator (DTI-2) developed by Philips Research, which has been found to reliably reflect the stress levels of a person [2]. This is a single wristband sensor that measures EDA between two electrodes placed on the skin. The sensor registers both rapidly changing EDA, reflecting short-term external stimuli, and more stable EDA, which corresponds to longer-term emotional changes regardless of external stimuli. The wristband stores measurements in an internal memory, and an online service filters the signal and eliminates rapidly changing components and noises such as spikes and noncontact values. The online service calculates a baseline for each participant to statistically classify stress levels on a scale from 0 to 5. The calculation of baseline and stress levels is explained in detail in the paper by Kikhia et al. [25]. The person with dementia wore the sensor during the day, and it was removed and charged during the night. Data from the wristband were transferred by the first author to the online service, which calculated the stress level of the person with dementia based on EDA.

Observation Scheme. To receive observational data on the time course and the frequency of naturally occurring targeted behaviors [26], assistant nurses involved in the daily care of the individual with dementia annotated observed behaviors on an observation scheme. Specific predetermined colors were used for each behavior, and behaviors commonly occurring in advanced dementia [27] were presented in the observational 24-h timeline scheme, including worriedness, aggression, and sleep. It was also possible to add information to the scheme if needed. Figure 1 shows an example of observation notes for a participant. Observation notes were collected for approximately 2 weeks for each participant, during which time the participant also used the sensor to register EDA.

Data Analysis

The data from the online service was transferred to IBM SPSS statistics predictive analytic software (version 23.0) along with the data from the structured observations. The data from the structured observations were dichotomized into two groups, consisting of observations of behaviors indicative of agitation (e.g., worriedness, aggression, irritation, restlessness) in

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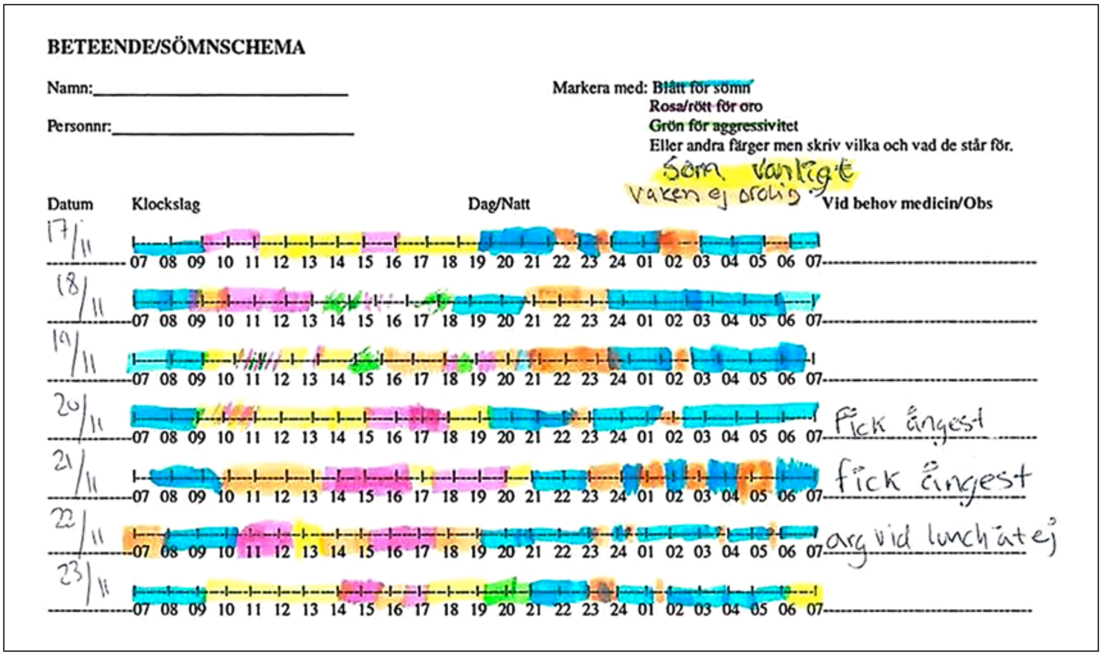

Fig. 1. Example of an observation scheme filled in by assistant nurses. Assistant nurses were provided with an observation scheme where specific predetermined colors were used for each behavior. Behaviors commonly occurring in advanced dementia were presented in the observational 24-h timeline scheme including worriedness, aggression, and sleep. It was also possible to add information to the scheme if needed.

one group and awake/calm in the other. Observations of sleep were excluded from the analysis as sleep was not within the study's scope. There were 192–195 data points with simultaneous observations and sensor values, depending on the time of the sensor values. A graph demonstrating the data from sensor values combined with structured observations is presented in Figure 2. The statistical significance was set at $\alpha < 0.05$. Differences between means were analyzed using the Student *t* test, and correlations between observations and sensor values were analyzed using the Spearman rho. To study the effect of sensor values at different time delays on the observations of agitation, a binary logistic regression model following Dawson and Trapp [28] was applied. The regression model allowed us to control for multicollinearity and to assess the relationship between the sensor measuring EDA and the assistant nurses' observations. The predicted variable was the assistant nurses' observations of agitation, and the three predictors were (1) sensor value at the time of the observation, (2) sensor value 1 h prior to the observation, and (3) sensor value 2 h prior to the observation. Predictors were entered into the equation simultaneously, and the Hosmer-Lemeshow goodness-of-fit test was chosen to evaluate the fit of the predictive model.

Results

A Student *t* test of equality of means revealed a significant difference ($p < 0.01$) in mean sensor value between individuals assessed by assistant nurses as showing agitation and individuals assessed as awake/calm, both at the time of the observation and 1 and 2 h prior to observation (Table 1). This indicates that mean sensor values were significantly higher when assistant nurses annotated agitation compared to when they annotated awake/calm.

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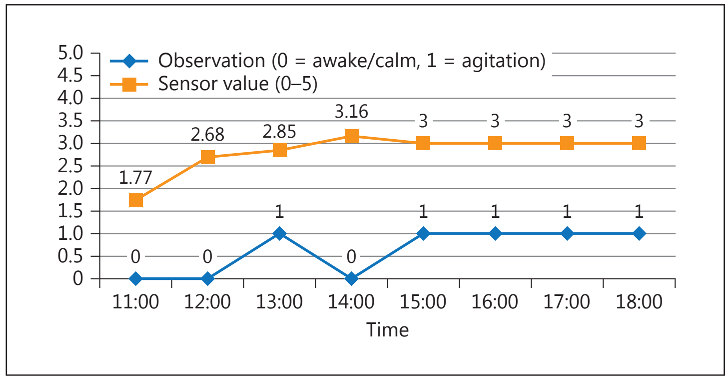

Fig. 2. An example of the structured observations made by assistant nurses combined with the sensor values. Observations made by assistant nurses indicates awake/calm (0) and agitation (1). An increasing sensor value (0–5) indicates an increase in electrodermal activity at the time of the observation.

Table 1. Differences in mean sensor values

Assistant nurses' observation	*n*	Mean (SD)	Mean difference	95% CI lower	95% CI upper
Sensor value at the time of the observation					
Awake/calm	71	1.69 (0.95)	–1.24	–1.56	–0.92
Agitation	121	2.93 (1.15)			
Sensor value 1 h prior to observation					
Awake/calm	73	1.65 (0.93)	–1.24	–1.56	–0.91
Agitation	121	2.89 (1.21)			
Sensor value 2 h prior to observation					
Awake/calm	79	1.69 (0.98)	–1.19	–1.50	–0.87
Agitation	116	2.88 (1.19)			

Student *t* test of equality of means revealed a significant difference ($p < 0.01$) in mean sensor value between individuals assessed by assistant nurses as awake/calm and individuals showing agitation, both at the time of the observation and 1 and 2 h prior to observation.

There was a significant correlation between assistant nurses' observations of agitation and sensor values both at the time of the observation and 1 and 2 h prior to the observation. The correlation decreased as the time span between sensor value and observation increased (Fig. 3), indicating that the correlation was strongest during simultaneous measurements. However, sensor values prior to the observation were also significantly correlated, indicating that increasing EDA values were seen prior to the assistant nurses' annotation of agitation.

In the binary logistic regression model, all predictors were entered simultaneously and were individually significant. As opposed to the individual correlations shown in Figure 3, the logistic regression model takes into account the joint effect of the sensor values at the different time delays. The omnibus test of model coefficients was significant ($\chi^2 = 47.0$, $p < 0.001$) with a Nagelkerke R^2 of 0.36. The Hosmer-Lemeshow test was nonsignificant ($\chi^2 = 11.02$, $p = 0.14$), indicating that the model's predictive capacity was good. Based on these results, we found no evidence suggesting any model deficiencies. The model presented in this paper correctly predicted 73.5% of assistant nurses' observations of agitation opposed to 66.5% with no predictors and 50.0% by chance. The results show a relationship between the assistant nurses' structured observations of agitation and an increase in EDA detected by the sensor at different time delays. The variables in the equation (Table 2) revealed that sensor value

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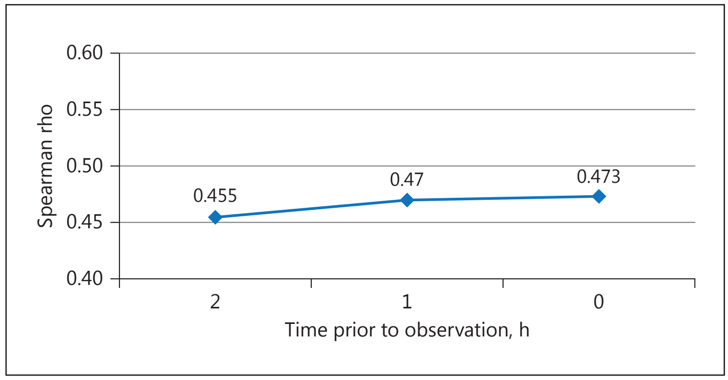

Fig. 3. Correlations between sensor values and assistant nurses' observations of agitation at the time of the observation (0 h) as well as 1 and 2 h prior to the observation. There was a significant correlation ($p < 0.01$) between assistant nurses' observations of agitation and sensor values both at the time of the observation (0.473) and 1 h (0.47) and 2 h (0.455) prior to the observation.

Table 2. Results of the logistic regression analysis

	Sensor value at the time of observation	Sensor value 1 h prior to observation	Sensor value 2 h prior to observation
Observation of agitation	2.20 (1.24–3.92)	0.97 (0.49–1.93)	1.78 (1.07–2.96)

Values are presented as exp(b) with 95% CI in parentheses. For every one-unit increase in sensor value, the odds of observing agitation increased by a factor of 2.20. Sensor values simultaneous with assistant nurses' observations had the largest predictive effect; sensor values prior to observation had a somewhat smaller effect.

simultaneous with assistant nurses' observations had the largest predictive effect. For every one-unit increase in sensor value, the odds of observing agitation increased by a factor of 2.20 (95% CI 1.24–3.92); sensor values prior to observation had a somewhat smaller effect. For every one-unit increase in sensor value, the odds of observing agitation 2 h later increased by a factor of 1.78 (95% CI 1.07–2.96). Sensor values 1 h prior to observation remained insignificant, probably due to multicollinearity, but the variable was included since it increased the model's predictability [29]. Inference from the model suggests a relationship between sensor values and assistant nurses' observations of agitation, and that the sensor has the potential to identify EDA prior to the observation of these behaviors.

In summary, the findings support our hypothesis that there is a relationship between the assistant nurses' observations of agitation and an increase in EDA detected by the sensor. The findings also support the hypothesis that the sensor indicates EDA prior to assistant nurses' structured observations of agitation.

Discussion

In this study, we found a correlation between assistant nurses' observations of agitation and a sensor measuring EDA. Additionally, the sensor has the potential to identify stress prior to assistant nurses' observation of agitation. According to Visnovcova et al. [30], EDA is sensitive to the detection of changes in the SNS with regard to mental stress; however, SNS activity is complex and thus also the regulatory mechanisms of EDA. The present study indicates that a sensor measuring EDA is sensitive to measures of agitation, but at the same time, the specificity of the measurements is questioned since both positive and negative emotions

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can increase EDA [31]. Khalfa et al. [32] demonstrated that EDA is sensitive to variations in emotional arousal, but not to emotional clarity and valence. There is a risk that positive emotions such as joy and happiness may result in an increase in EDA [31], which, in turn, can be interpreted as negative stress. Here, we emphasize the importance of using EDA as a tool to aid nursing staff in the understanding of agitation rather than as a stand-alone system. In this process, nursing staff working close to the person with dementia are important for filtering misguiding EDA measurements when trying to detect agitation. Kreibig [31] emphasizes the importance of studying patterns in emotions and measures rather than single, isolated changes. We also suggest that the time period that the sensor is used should be carefully considered due to individual variations and since data collected over a short time may be misguiding.

Person-centered care requires an understanding of the individual, which can be challenging in the demanding everyday nursing practice, where interruptions and work routines may complicate nursing staff's ability to develop a clear picture of each person's situation and life [33]. Our findings indicate that the use of a sensor measuring EDA can add to the understanding of agitation by providing a more comprehensive picture of the situation of the person with dementia. The sensor can identify signs of stress regardless of staff presence and has the potential to provide regular and objective information in addition to steady monitoring. According to Cohen-Mansfield et al. [1], assistant nurses may underestimate the true needs of individuals with dementia or fail to notice unmet needs. In this process, a sensor measuring EDA contributes information collected over time, adding an objective element to otherwise subjective assessments and monitoring conducted by nursing staff. In turn, this strengthens the recognition and understanding of needs, which is of essence for supporting the well-being of persons with dementia [1].

The findings in this study indicate that a sensor measuring EDA can detect signals of stress prior to nursing staff's observations of agitation. This can support nursing staff to place behavior in context at the time it occurred. McCormack [34] emphasizes that how a person reacts depends on who the individual is and how he or she makes meaning out of different situations and activities. To interpret and understand behaviors as they occur enhances the overall understanding of the individual, thereby affecting the decisions and care provided. Early identification of stress can enable nursing staff to plan, customize, and implement preventive measures, thereby reducing the occurrence of stress in individuals with dementia and providing a more person-centered care. To be able to address and understand agitation and unmet needs in people with dementia, Cohen-Mansfield et al. [1] stress the importance of understanding their causes and triggers. Based on our findings, we suggest that contributing information from a sensor measuring EDA can support nursing staff to better identify patterns, triggers, and stressful events. Enhanced identification of stressful events can assist nursing staff in tailoring care interventions towards causes and triggers and reaching a more preventive approach.

When providing person-centered care for individuals with dementia, the necessity of taking the context into consideration is evident when attempting to understand the individual [34]. In this study, a sensor measuring EDA may enhance the understanding of agitation in people with advanced dementia; however, it does not tell nurses what to do, and it does not take into account the individual's values and beliefs. Here, it is important to address the limitations of technical aids. By combining measurements with nurses' knowledge of the individual, the sensor can provide additional information in the process of understanding the individual's condition. Person-centered nursing aims to transform the individual's experiences and perception of the situation to guide and steer the nursing staff's support [34]. A sensor measuring EDA can be seen to provide continuous monitoring and act as one way for the individual to mediate his or her experiences and needs, which can then be used as information when attempting to form the basis of care for that person. At the basis of this study, we argue that a sensor measuring EDA may support assistant nurses in forming a more comprehensive picture of agitation and contribute information prior to the assistant nurses observing it. This may in turn enhance the support provided to be more person-centered and preventive, since the focus can be directed towards peaks of stress, and causes and triggers can be targeted more effectively.

Methodological Considerations

Data were collected from a total of nine participants. This is a relatively small sample size, but challenges in recruitment, time-consuming data collection, and the necessity for careful ethical considerations limited the possibility to include more participants. The data were collected from five different wards within four different dementia care units in two different cities, which added variation in both participants' characteristics and environmental factors. There were data losses when the individual with dementia removed the sensor or nursing staff forgot to attach it. There were also occasions when nursing staff forgot to annotate in the observation scheme or were not observing the participants, and thus were unable to identify episodes of agitation. These factors are difficult to control in a real-world setting and might explain the relatively low correlation coefficient (0.473, $p < 0.01$) between observations and sensor values. We excluded data points where data were missing from either the sensor or the observation scheme. However, the number of data points was considered sufficient to perform the analysis.

The observation scheme used in this study is used by many dementia care units, which enhanced the possibility of accurately measuring what was intended. It is simple and has a structure and language that assistant nurses are used to and can recognize [24]. This is important when performing data collection in real-world settings, where any additional burden may increase the likelihood of not receiving accurate information [26]. However, this meant that more detailed observations were omitted. The interobserver agreement between them was not examined and would probably show differences as a consequence of different opinions and perceptions among assistant nurses with regard to observed behaviors. Still, the assistant nurses working at the dementia care units were chosen due to their close relationship to the person with dementia and their experience in assessing these kinds of behaviors.

Strong arousal emotions, such as fear and happiness, have been shown to be related to higher EDA values [32]. There is a risk that positive emotions may have resulted in an increase in EDA and were incorrectly classified as stress. To strengthen the validity of this study, the mean value for stress was compared to and aligned with the threshold value for EDA for people with dementia suggested by Kikhia et al. [25]. The activity of the SNS varies with age [35], and older people may show attenuated EDA [36]. Lesions in different parts of the brain [37, 38] and different types of dementia have been shown to affect the level of EDA due to for example emotional blunting [39]. However, measurement of EDA has been found to be a reliable and valid method for indicating arousal, and the use of sensors measuring EDA in people with various neurodegenerative diseases has been well studied and described [40]. Even so, it is important to be aware of changes and differences in EDA when considering EDA measurement in people with dementia.

Conclusion

Understanding agitation is an essential part of the care for people with dementia worldwide. To enhance the understanding of individuals with dementia, exploring alternatives to improve the identification of these behaviors is important. Using a sensor that measures EDA shows correlations with observations of agitation made by assistant nurses. In addition, sensor measurements can be used to correctly predict 73.5% of the observations of agitation, and the sensor also indicates EDA prior to the observations. It has the capacity to detect activity in the SNS, but lacks the ability to differentiate negative emotions from positive ones or other causes. Thus, the sensor cannot replace nursing staff for interpreting and understanding EDA in relation to the individual. Measurements of EDA may support nursing staff in gaining a more comprehensive picture of the individual's situation and identifying stress earlier, thereby targeting its causes and triggers more effectively. This is a crucial element for attempting to decrease agitation and support the lives of people with advanced dementia.

Future Research

The time period needed to monitor stress in order to identify behavioral patterns should be further studied. Future research is also needed to study how the sensor can be used and integrated in a clinical setting, e.g., the transfer of information from the sensor to the nursing staff should be further investigated, building towards the possible development of an alert system. To create routines that strengthen nursing staff's response to the individual with dementia's signals of agitation, future research evaluating the impact of using a sensor measuring EDA in a clinical setting is needed.

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Disclosure Statement

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