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Adolescent adherence to orthopedic brace wear: A behavioral assessment of high risk factors

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Adolescent Adherence to Orthopedic Brace Wear:
A Behavioral Assessment of High Risk Factors

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This dissertation project is dedicated to my beloved husband, Peter.

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Abstract

An important challenge physicians encounter when treating adolescent patients with moderate scoliotic curves is that the adolescents may not wear the brace as prescribed or long enough for the brace to be effective. The present investigation used electronic monitoring and temperature probes to investigate whether the adolescents were wearing their brace during events identified using a modified Daily Reconstruction Method for six randomly selected days over a 14-day period. It was hypothesized that environmental, interpersonal, and intrapersonal variables during the events would be predictive of objective brace-wear across and within participants, and patterns of significant variables would differ from subjective reports of brace-wearing. Participants were nine ethnically diverse adolescents (two male, seven females) with a mean age of 13.25 years, who provided 47 – 81 events each for a total of 567 observations. When analyzing whether the adolescents were wearing their braces during events, the results of a logistic regression across participants suggests adolescents did not wear their braces when participating in *physical activities,* when with *parents* and *non-related adults,* during *hygiene* activities, and when in a more *negative mood.* As a group, the adolescents in this study were more likely to wear their brace when they were *studying at school* and when they feel *competent.* For individuals, other variables, such as *riding in vehicles, eating, shopping,* and *comfort* were associated with not wearing their brace. The main discrepancies in objective and subjective measures of whether they were wearing their brace-wearing were intrapersonal situations. The adolescents were less likely to not report not wearing their brace when they were in a more *negative mood,* and but were more likely to when they were *uncomfortable*. Importantly, this investigation was successful at pioneering a replicated single-case design to assess both

objectively measured brace-wearing and environmental, interpersonal, and intrapersonal psychosocial variables within and across participants. This innovative use of DRM methodology is generalizable to research investigating a wide array of adherence behaviors and measuring their predictors proximally in time but without reactivity typically caused by interrupting ongoing activities.

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Introduction

Scoliosis is a chronic health condition that is characterized by abnormal curvatures of the spine greater than 10 degrees (also referred to as Cobb angle of >10°) and is diagnosed in approximately 2 - 4% of the population, totaling about 6 million adolescents. Unlike curves due to congenital and neuromuscular abnormalities, Adolescent Idiopathic Scoliosis (AIS) has no known cause but is thought to be a multigenic dominant condition with variable phenotypes (Reamy & Slakey, 2001). Although the onset can be at any age, it is most common in adolescents 8 -18 years old. Either gender may be affected, but because their curves are greater and progress more quickly, females are eight times more likely to require treatment. Curves can progress during puberty if not adequately treated before skeletal maturity. Skeletal maturity is assessed by the Risser sign greater than four (the amount of calcification present in the iliac apophysis) and less than one centimeter of change in height for females.

Although alternative treatments such as biofeedback and electrical stimulation exist, standard treatments are structured observation (also referred to as “watchful waiting”), bracing, or surgery. If curves are less than 25 degrees, physicians usually watch for signs of progression. About 30,000 adolescents each year are prescribed braces for curves between 25 and 45 degrees to arrest curve progression, and approximately 38,000 per year undergo surgery for curves that have progressed beyond 45 degrees (Richards, Bernstein, D'Amato, & Thompson, 2005).

An important challenge physicians encounter when treating adolescent patients with moderate scoliotic curves is that the adolescents may not wear the brace as prescribed or long enough for the brace to be effective. If the progression of the curve cannot be halted

with a brace, patients may be faced with having to undergo surgical spinal fusion to correct the curves or having to live with severe curves that may negatively affect functioning as they mature (Bowen, Keeler, & Pelegie, 2001; Katz & Durrani, 2001; Wiley, Thomson, Mitchell, Smith, & Banta, 2000). Some studies have shown as many as 64% of high school age patients may be non-adherent with wearing a brace (Gurnham, 1983).

The current investigation examined the variables associated with adolescent brace-wearing. What follows is a review of the literature, examining how best to define adherence, the consequences of not adhering to wearing a brace, the popular theoretical models of adherence and how they might or might not apply to brace-wearing, how constructs within the Behavioral Analytic Model shed light on brace-wearing adherence, the state of the current assessment methods and a new method of proximally assessing behaviors, the state of current design methods, and the benefits of using a longitudinal design for empirically investigating brace-wear adherence. Following the literature review will be a description and discussion of a preliminary investigation that was needed to gather information about the target population and inform construction of the new assessment method. Thereafter, the unique research method used in the the main empirical investigation will be described. The results of this investigation will be discussed highlighting assessment and design benefits and significant results in terms of the theoretical models.

Defining Adherence

Before discussing adherence to brace-wearing, a clarification of the term and the relationship with treatment improvement would be prudent. Whereas some researchers still use the term *compliance*, the synonym *adherence* is now preferred. The connotation of "compliance" suggests that the patient is a passive participant and subservient to the

practitioner who prescribes a treatment regimen. It follows that patients should follow the practitioner's advice and if they do not, the assumption is that something is wrong with the patient, who is thus labeled *noncompliant*. Conversely, adherence implies an active and voluntary role for the patient, wherein the patient has agreed to follow the advice and may have participated in determining the regimen characteristics. The patient is viewed as a decision-maker who continuously evaluates if, when, and how he or she will perform the target behavior. To help clarify and direct the literature, the World Health Organization (WHO) has adopted use of the term *adherence* and, through consensus, has defined adherence as "the extent to which a person's behavior – taking medication, following a diet, and/or executing lifestyle changes, corresponds with agreed recommendations from a health care provider " (Sabaté, 2003, p. 3).

The relationship between degree of adherence (as indicated by dose) and condition improvements vary by disorder and treatment. Relationships can be viewed as fitting on-off, linear, curvilinear, and threshold models (Kravitz & Melnikow, 2004). In the on-off model, which may be applicable to antiviral therapies, benefits are negligible until adherence reaches near 100%. In the linear and curvilinear models, which may be applicable to antihypertensive therapies, benefits increase with increasing adherence behaviors. In the threshold model, which may be applicable to aspirin therapy to prevent myocardial infarction, benefits are not experienced until a certain adherence level is attained and the added benefits are no longer experienced when the dose is increased past a certain level. Adding to the variation, dose responses frequently vary across individuals, so clearly defining effective adherence rates is necessarily disease-, treatment-, and individual-specific. These considerations have rarely been taken into account when categorical cutoffs

for adherence have been determined in research investigations. Patient behaviors are often labeled as adherent or non-adherent when a threshold percentage of behaviors is met or not met. Alternatively patient behaviors may be categorized as good, moderate, and poor when the samples are trifurcated (La Greca & Bearman, 2003), an approach which may not be clinically meaningful. For these reasons, for research purposes continuous measures of adherence or carefully investigated cutoffs that are linked to meaningful disease outcome evidence are preferred to arbitrary or study specific cut-offs.

With respect to AIS brace adherence, in one study as many as 92% of adolescents with scoliosis who wore their brace less than 12 hours a day had Cobb angle progress beyond 45º (Wiley et al., 2000); in another study, curves progressed for 56% of adolescents who complied less than 90% (Yrjonen, Ylikoski, Schlenzka, & Poussa, 2007). In contrast, only 4% of adolescents with scoliosis who wore their brace more than 18 hours a day had Cobb angle progress more than 45º (Wiley et al.) and curves progressed for only 11% of adolescents who complied more than 90% (Yrjonen et al.). Longer durations of brace-wear have often been associated with increasingly less curve progression (Bowen et al., 2001; Katz & Durrani, 2001; Wiley et al., 2000; Yrjonen et al., 2007), suggesting that adherence rates have a negative linear relationship to the progression of spinal curves. Therefore, the present study focused on the daily amount of time adolescents wore the brace and which situations predicted or were associated with wearing the brace longer.

In the brace-wearing literature, arbitrary and investigation-specific cutoffs weaken inferences about the links between behavior and disease improvement and make comparisons across studies difficult. For example, it is difficult to compare the benefits of brace-wearing when one study defined adherence to brace-wearing with full-time brace

wearing at greater than 90% of prescribed time (Rahman, Bowen, Takemitsu, & Scott, 2005), another as greater than 78% (Bowen et al., 2001; Wiley et al., 2000), or as when the brace is worn more than just at night or occasionally (Yrjonen et al., 2007).

Another problem interfering with defining adherence behaviors is that inadvertent and volitional non-adherence are posited to be two different classes of behaviors associated with different causes and influential factors and, thus, require different interventions (Bauman, 2000). Inadvertent non-adherence occurs when individuals accept the treatment advice, believe that they are adhering, and may be working hard at being adherent, but face obstacles to adequate adherence, acknowledge missing doses occasionally but are not concerned about it, have misunderstood what is expected, and/or have been given incorrect instructions. Inadvertent non-adherence may be predicted by patient characteristics, developmental characteristics, and provider/system characteristics (Bauman, 2000). On the other hand, volitional non-adherence occurs when an individual makes a reasoned choice not to adhere. Volitional non-adherence may be predicted by the difficulty and disruptiveness of medical regimen, skepticism about efficacy, presence of side-effects, cost of treatment, denial of diagnosis, physician prescribing practices, and patient beliefs, fears, and concerns (Bauman, 2000). Furthermore, patients who believe they are adhering may underreport more than those who deliberately misrepresent the degree of adherence. Since intervening when it is not perceived as needed may actually do more harm (Rapoff, 1999) and choosing ineffective interventions may be costly, researchers and clinicians should consider differentiating between the two types of non-adherence.

As an example of inadvertent non-adherence in the AIS population, 30% of the adolescents have been found to wear the brace too loose to be effective (Lou et al., 2004). In

addition, the factors associated with wearing the brace ineffectively may be associated with patient characteristics, such as age, or system factors that affect recalling instructions. In contrast, removing the brace purposely may be more associated with the patient's belief in the effectiveness of the brace or fear about others' reactions. Given the evidence and concerns about defining adherence and the types of adherence, the present investigation did not categorize adherence as a binary variable (adherence as opposed to non-adherence). Instead, in order to contribute to understanding how to aid adolescents with wearing their brace longer, this investigation explored the daily duration of brace-wearing and whether the adolescents purposefully or inadvertently did not wear their brace.

Negative Ramifications of Adherence Behaviors

Non-adherence is a significant problem for many chronic illnesses or disorders, not just for AIS. In order to manage chronic illness or disorders such as diabetes or asthma, patients are asked to take medication consistently, use orthotics, and/or make lifestyle changes. However, making consistent positive health choices is difficult for many individuals. When the prescribed procedures or changes are not followed, not only are there consequences for the individual, but non-adherence has repercussions for clinical service providers and organizational and societal systems as well.

In general, individuals are at greater risk of poor health, hospitalization, and even death due to not adhering to medical recommendations. For example, in the general population, adherence rates have been shown to be negatively related to physical health across samples of participants with diabetes, hypertension, or heart disease (Sherbourne, Hays, Ordway, DiMatteo, & Kravitz, 1992) and accounted for 26% of medical outcomes (DiMatteo, Giordani, Lepper, & Croghan, 2002). For adolescents and children with diabetes, 75% of the cases of ketoacidosis (DKA) resulted from missed or incorrect insulin doses

(Bismuth & Laffel, 2007). Aside from short-term threats of ketoacidosis and hyperosmolar coma, poorly controlled diabetes increases the long-term risks of heart disease, stroke, high blood pressure, blindness, kidney disease, nervous system disease, amputation, and dental disease (Center for Disease Control and Prevention [CDC], 2004). The childhood asthma literature provides additional examples. Ten percent of children and adolescents have asthma and represent 50% of the emergency department visits. Even though primary care visits cost five times less than emergency room visits, as many as 43% of children and adolescents do not follow through with recommended primary care visits for asthma yearly (Kruzikas et al., 2004). Like adolescents and children with asthma and diabetes, adolescents with moderate back curves face worsening of their condition and increased costs. For adolescents with scoliosis, as many as 75% who wore their brace less than 12 hours a day required fusion surgery (Wiley et al., 2000).

Poor adherence rates also affect healthcare providers when they cause misinterpretations of treatment efficacy, increased utilization of higher cost services, and poorer treatment outcomes. Low adherence may contribute to prematurely altering or discontinuing treatments (Heidenreich, 2004). It is estimated that 25% of physician recommendations are not followed (Cherry, Burt, & Woodwell, 2003), resulting in 206 million wasted office visits (DiMatteo, 2004), which may be especially burdensome in systems that require the provider to share or assume all of the risk, when patient availability decreases as patients are referred elsewhere, or contracts are not renegotiated due to high utilization and poor outcomes (Armenti, 1999). For example, for patients not responding to part-time brace-wearing schedules, a physician may come to regard part-time schedules as ineffective and subsequently prescribe a greater frequency of full-time brace-wearing or

increase his recommendations for fusion surgeries when the poor outcomes from brace-wearing are more likely the result of poor adherence.

The third party payers are directly burdened by the costs of non-adherence, which are estimated to be as high as $100 billion in the United States (Berg, Dischler, Wagner, Raia, & Palmer-Shevlin, 1993), costs ultimately borne by the public. Contributing to the costs of healthcare, each year 30,000 of the six million cases of scoliosis are expected to need to wear a brace, but if the curve progression is not arrested, they may become one of the 38,000 expected to undergo spinal surgery or risk respiratory, muscular/skeletal, and circulatory complications as they age (National Scoliosis Foundation, 2005). Not only would the cost of expensive braces and monthly appointments be wasted, but the cost of $46,000 for each fusion surgery each would be incurred (Brown, 2002).

In summary, despite the fact that adherence to medical procedures has been investigated for several years, non-adherence continues to contribute to poorer health and even death for individuals diagnosed with chronic illnesses. In an increasingly efficiency-driven system, healthcare providers may find their organizations suffer when the effects of non-adherence on treatment outcomes are misinterpreted. In the end, the public shares the burden of the substantial direct and indirect health care costs of non-adherence. Given that non-adherence to wearing an orthopedic brace prescribed for scoliosis wastes the expenditures incurred during the original treatment and may lead to more costly procedures, non-adherence to brace-wearing contributes to the national healthcare burden. Therefore, a clear understanding of the variables that would increase brace-wearing is needed to assist healthcare professionals treat patients with AIS and so reduce patients' future suffering and healthcare costs.

Adolescent Brace-wearing

Despite the fact that wearing an orthopedic brace over 18 hours has been found to be associated with successfully reducing spinal curve progression, compared to when braces were worn less (Bowen et al., 2001; Katz & Durrani, 2001; Wiley et al., 2000; Yrjonen et al., 2007), the variables affecting adolescent brace-wearing have not been systematically investigated. AIS adherence studies fall into two camps, those that used objective measures and others that used more subjective measures of adherence. Only eight studies have investigated the patterns of brace-wearing using objective measures (Edgar, 1998; Helfenstein et al., 2006; Lou, Benfield, Raso, Hill, & Durdle, 2002; Lou, Hill, Raso, Mahood, & Moreau, 2006b; Lou, Raso, Hill, Mahood, & Moreau, 2004; Morton, Riddle, Buchanan, Katz, & Birch, 2008; Nicholson, Ferguson-Pell, Smith, Edgar, & Morley, 2003; Takemitsu, Bowen, Rahman, Glutting, & Scott, 2004; Vandal, Rivard, & Bradet, 1999).

The objective studies showed the actual average adherence rates, found to range from 33% to 75%, were substantially less (at least by 150%) than adherence self-reported by adolescents to range from 85% to 89% (Takemitsu et al., 2004; Nicholson et al., 2003; Vandal et al., 1999). Measuring pressure at the corrective or “apex” points of the brace added the information that 30% of the time the adolescents wore their brace too loosely to provide benefits (Lou et al., 2004). Furthermore, older adolescents have been found to be consistently less adherent to brace-wearing than younger children (DiRaimondo & Green, 1988; Edgar, 1998; Gurnham, 1983; Korovessis, Zacharatos, Koureas, & Megas, 2007; Takemitsu et al., 2004). Adherence rates also appear to peak at four and eight months after brace-wearing was initiated, and decline significantly after two years (Edgar, 1998). The effects of the settings are less consistent: one study indicated that adherence to brace-

wearing was better at nighttime (Korovessis et al., 2007; Nicholson et al., 2003) and another during the day time (Vandal et al., 1999). Although Edgar indicated that adherence rates were higher during the school year, another study suggested that being out of school did not alter adherence rates (Lou et al., 2002). Unlike other adherence behaviors that suggest the dosage frequency influenced adherence rates, the length of time the adolescents were instructed to wear the brace did not appear to influence adherence rates; adherence to part-time brace-wearing was similar to full-time rates (DiRaimondo & Green, 1988; Takemitsu et al., 2004).

Seven studies have investigated the psychosocial factors associated with adolescent brace-wearing (Andersen, Andersen, Thomsen, & Christensen, 2002; Climent & Sanchez, 1999; DiRaimondo & Green, 1988; Gurnham, 1983; Korovessis et al., 2007; Lindeman & Behm, 1999; Wickers, Bunch, & Barnett, 1977), but these studies used retrospective self-reports and chart reviews, methods of questionable reliability. Nevertheless, the findings suggest that subjective reports differ from actual wear and that age, gender, treatment duration, discomfort, expectations, self-efficacy, daily concerns, settings, and family and medical professionals' factors contribute to adolescent brace-wearing.

Some of the most frequently endorsed reasons for not wearing the brace include pain, skin problems, and social issues (Andersen et al., 2002; Korovessis et al., 2007). A retrospective study found 34 to 37% did not wear the brace because of pain and skin problems and 16% thought the brace was unpleasant and would rather risk curve progression; 10% reported giving up due to discomfort; 11% did not wear their brace because of a boyfriend/girlfriend relationship; 13% thought the brace caused them to be reserved concerning relations with the opposite sex; 13% did not wear the brace because of

friends; 43% tried to keep the brace a secret; and 13% reported actually experiencing harassment (Andersen et al., 2002). Andersen and colleagues also reported that wearing a brace as prescribed was the reported reason for 54% of the adolescents who refrained from activities and 23% who give up sports.

Similarly, pain and psychosocial reactions to their relations with peers and teachers, as surmised from less brace-wear by adolescents during school hours, were the main cause of poor adherence in a prospective study (Korovessis et al., 2007). The more months an adolescents had worn a brace, the less likely they were to lose friends, but the less likely they were to spend time with friends. Adolescents who wore the brace less were more likely to have sleep problems, wake up due to pain, and have more problems due to lack of flexibility.

A recent prospective study that assessed cognitive and attributional variables and objectively measured adherence found that pretreatment expectation and knowledge about treatment, attitudes toward healthcare professionals, peer and family influences, and beliefs about health self-efficacy were associated with brace-wearing (Morton et al., 2008). However, the unique contributions of each variable could not be determined because the psychosocial variables in this study were not individually assessed but summed as a single total score for the Brace-Beliefs Questionnaire (Morton et al.).

Gender differences in adherence factors have been noted. Higher success expectation, more seeking of social support, and higher self-esteem predicted higher adherence for females but lower adherence rates for males (Lindeman & Behm, 1999). Girls were less likely to adhere and more likely than boys to experience back pain, have problems

with sleeplessness, feel ashamed of their bodies, and regard their bodies as unattractive than boys (Korovessis et al., 2007).

Adolescents from intact families were found to be more adherent and more likely to complete treatment than those from non-intact families (Gurnham, 1983). Interpreting these data should be done with caution, as intact family status may be less reflective of marital status and more reflective of family resources, such as amount of and level of supervision.

Given the variables that have been investigated so far and despite methodological problems in the few extant studies, the findings to date suggest brace-wearing adherence rates remain a significant problem, and investigators attribute adherence rates to experiences with situational (e.g., activities), environmental (e.g., discomfort), interpersonal (e.g., social and family interactions), and intrapersonal (e.g., health belief) factors. Future investigations of adolescent brace-wearing should systematically investigate these daily concerns and objectively measure actual adherence behaviors.

Models of Adherence Behaviors

Investigations of adherence behaviors have examined many variables, but not always in a systematic or useful fashion. Some of the general factors that have been identified as correlated with adherence are age, gender, and socioeconomic status (SES), illness type, illness duration, illness severity, treatment complexity, knowledge of the disease and treatment, treatment cost, environmental barriers, treatment efficacy, and patient/provider alliance. Table 1 shows a risk profile for pediatric adherence that has been developed based on modifiable and non-modifiable correlational variables (Rapoff, 1999). Nevertheless, the findings from correlational studies that are not based on theory have the potential to identify spurious or non-modifiable variables. For example, interventions based on theory have been found effective in increasing adherence to annual health screenings (behavioral by 13.2%

and cognitive by 23.6%), but interventions that were not based on theories were not effective (Yabroff & Mandelblatt, 1999). Therefore, approaching adherence from a theoretical background may be most effective, and an examination of the models that have been used to understand health behaviors is warranted.

Table 1
Risk Profile for Pediatric Non-Adherence

Construct	Variable
Family	Preoccupied with dysfunctional interaction patterns
	Several social and recreational activities outside home
	Larger families*
	Lower SES*
	One parent household*
Parent	Less education*
	Less informed about illness
	Preoccupied with own adjustment and coping problems
Child or adolescent	Older age*
	Adjustment or coping problem
	Less knowledgeable of disease and treatment
	Bears primary responsibility for carrying out regimen tasks
Disease	Longer duration*
	Fluctuations in symptoms*
Regimens	Complex
	Intrusive
	Costly
	Negative side effects
	Not immediately beneficial*

Modified from Rappoff, 1999
*non-modifiable variable

The theories that explain adherence behaviors focus on two types of behavior change processes: cognitive or self-mediated thought processes (e.g., self-efficacy or rule-governed behavior) on the one hand, and environmental contingencies (e.g., cues and consequences) on the other. Whereas cognitive models concentrate on the influence of the individual's evaluation of the health situation and their related choices, behavioral models concentrate on the situational stimuli that alter the individual's evaluations and responses. The Health Belief Model, the Theory of Planned Action, the Social Cognitive Theory, and the

Transtheoretical Model are representative of the cognitive theories commonly used to conceptualize adherence behaviors, and the Self-management and Relapse Prevention models are representative of the cognitive-behavioral theories. However, as argued below, these cognitive models may be too general and distal (remote in time) from actual situations. Therefore, the current investigators posit that a Behavioral Analytic model would furnish a greater understanding of the proximal (close in time) reasons for adolescents not wearing their brace.

Cognitive Models

Health Belief Model (HBM:Janz & Becker, 1984). One of the most frequently employed models for explaining and predicting adherence to health and medical recommendations is the HBM. Even though this model was originally developed to investigate preventative health behaviors, later it was applied to help seeking and following medical regimens (Clark & Becker, 1998). The model hypothesizes that a person is likely to take action if they are sufficiently motivated and believe they are susceptible to the disease or complication and that doing so will be beneficial for an acceptable cost (Rosenstock, Strecher, & Becker, 1988). The combined levels of perceived susceptibility and perceived severity are thought to provide the motivation to act, while the perceived benefits minus the perceived costs or barriers provide information about the means of action (Janz & Becker, 1984). Furthermore, internal or external stimuli or "cues to action" are surmised to activate the individual's decision-making process. Demographic and sociopsychological factors impact actions indirectly by influencing the individual's perceptions of susceptibility, severity, threats, benefits, and barriers. More recently, self-efficacy, which had been viewed as part of the perceived benefits variable (Janz & Becker, 1984), has been separated out and

treated as an important unique variable in the current model that is often referred to as the Expanded Health Belief Model (Charron-Prochownik et al., 2001; Rosenstock et al., 1988).

Studies have strongly supported some of the constructs of the model but only weakly supported others, especially in adolescent populations. Across 12 prospective and 17 retrospective investigations, barriers were significantly related to adherence in 91%, benefits in 81%, susceptibility in 77%, and severity in only 59% of the investigations in which they were measured (Janz & Becker, 1984). For adolescents with insulin dependent diabetes, the entire HBM accounted for 23-25% of the variance in reported adherence to medicine regimens and self-care (Bond, Aiken, & Sommerville, 1992). More importantly and contrary to the model, increased threat was associated with reduced adherence when the benefits of treatment adherence were high. The HBM was also not well supported for adolescent girls with diabetes: whereas fewer perceived barriers, greater self-efficacy, and increased motivational cues were predictive of choosing effective birth control, only self-efficacy and intention were predictive of actual use (Charron-Prochownik et al., 2001). Together, these findings provide only limited support for the use of the HBM to predict adolescent adherence behaviors.

Theory of Planned Behavior (TPB; Ajzen, 1991). The TPB hypothesizes that an individual's beliefs about the behavior, social norms, and control over the situation motivate the intention to act and thereby influence the behavior (Ajzen, 1991). The model is limited to when the behavior is under volitional control and the individual has the opportunity and resources needed to act. Attitude toward behavior (82%) and perceived behavioral control (85%) consistently demonstrated predictive significance in 56 studies examining the intention to perform health-related behaviors, but the impact of social norms (47%) was

more variable (Godin & Kok, 1996). More important to research on actual adherence behaviors, such as wearing a brace, intentions account for only 22% to 33% of variance in the actual performance of the behavior of interest (Armitage & Conner, 2001). In other words, an adolescent may only follow through with wearing the brace in fewer than one-third of the situations in which, based on their attitudes, perceived control, and beliefs of social norms, they report intent to wear their brace. Therefore, the TPB model is not very useful for identifying the predictors of adolescents' actual brace-wearing.

Social Cognitive Theory (SCT; Bandura, 1977)). Initially developed to analyze phobic reactions, SCT has also been applied to health behaviors. The two major components, perceived self-efficacy and, to a lesser extent, outcome expectations, are posited to influence all aspects of behavioral initiation, effort, and duration of effort when faced with barriers to adherence (Bandura, 1977, 1996). Although vicarious experience, verbal persuasion, and emotional arousal provide efficacy information, actual performance accomplishments (and failures) are considered especially influential. For adolescents wearing braces, this would imply that their own personal experiences with wearing the brace would have more influence of future brace wearing than the experiences of others, persuasion from parents or medical professionals, or a positive mood. In addition, not only does the information generalize across similar situations, but it may also be differentially affected by social, situational, and temporal factors, suggesting that strongly held efficacy beliefs are more likely to be strengthened if the individual accomplishes the new behavior in a similar situation. This means that adolescents may feel more self-efficacious and wear their brace in situations similar to past brace-wearing but not necessarily when the social, situations, or temporal variables differ or change.

Reviews of empirical studies demonstrated that manipulations in information about performance altered participants' beliefs and subsequent behavior in laboratory settings (e.g., tolerance to cold-pressor; Bandura & Locke, 2003) and various health-related behaviors in clinical samples (i.e., smoking, weight control, contraceptive use, alcohol use, and exercise; Strecher, DeVellis, Becker, & Rosenstock, 1986). However, it is also argued that the participants were given information on their performance that altered their prediction of future performances and that self-efficacy is only an index of the individual's summation of various past performances (Hawkins,1995). Although the SCT model may predict adherence behavior, such as brace-wearing, by itself the SCT model does not provide enough information to identify the direct predictors of adherence behaviors.

Transtheoretical Model (TTM; Prochaska, 1979)). The TTM originally conceptualized readiness to change in psychotherapy (Prochaska, 1979) and addictive behaviors (Snow, Prochaska, & Rossi, 1994) but now includes initiating and maintaining changes in health behaviors (Prochaska, DiClemente, & Norcross, 1992; Prochaska et al., 1994). Two dimensions, stage of change and process of change, articulated when and how individuals change behaviors. Individuals are hypothesized to use overt and covert behaviors (Rosen, 2000) to move through the precontemplation, contemplation, preparation, action, and maintenance stages in often nonlinear relapse and recycling patterns (Prochaska et al., 1992). Two new constructs, decisional balance and self-efficacy, were later added to the original model (Prochaska & Velicer, 1997). Decisional balance or the individual's attitudes that give weight to the pros and cons of the behavior has been observed to shift predictably between precontemplation and action stages. Self-efficacy has also been posited to influence the individual's degree of confidence that they can cope with high-risk situations and the

degree of temptation. For adolescents with scoliosis, this would entail weighing the pros of wearing the brace (e.g., straighter back in future) against the cons (e.g., embarrassment in front of friends) and making the general decisions whether they are ready and able to wear their brace continuously. However, although the TTM model may assess when the adolescent is agreeable to wearing their brace as a treatment option, it has limited utility because it does not predict specific situations that may lead to not wearing their brace.

Cognitive-behavioral Models

Self-Management Model (SMM;Lorig et al.,1999). Based on the assumption that whether or not an individual performs a healthy (or prescribed) behavior, the individual is constantly engaged in the management of behaviors, Self-Management Models focused on the individual's shifting perspectives and day-to-day problems related to maintaining healthy behaviors (Lorig & Holman, 2003; Lorig et al., 1999). Derived from work with asthma patients, self-management tasks more generally can be identified as medically managing the condition (e.g., wearing a brace), maintaining or changing the meaning in life roles (e.g., altering style of clothing), and dealing with the emotional sequelae of having a chronic disease (e.g., embarrassment). Although five core self-management skills (i.e., problem-solving, decision-making, utilizing resources, forming of patient/provider partnership, and taking action) are employed to maintain or change health behaviors, self-efficacy is also viewed as a key component. Not only have Chronic Disease Self-Management Programs been shown to reduce medical utilization and health distress and increase self-efficacy across chronic medical conditions (Lorig et al., 2001), but the improvements in self-efficacy were uniquely associated with reduced medical utilization. Similarly, for child and adult participants, problem-solving skills and self-efficacy were

associated with adherence to diabetes regimens, whereas increased knowledge alone usually produced non-significant or even adverse effects (Hill-Briggs, 2003). The Self-Management model may be useful in conceptualizing treatment components but again relies heavily on measures of self-efficacy instead of measuring the maintaining (or barrier) variables directly. Therefore, in the current investigation of the predictors of brace-wearing, the investigator deemed a more direct approach as desirable.

Relapse Prevention (RP; Marlatt & Gordon, 1985). If adhering to new behavior patterns is viewed as adopting new responses to existing situations (e.g., making new food choices), the Relapse Prevention (RP) model can be applicable. The model surmises that when faced with a high-risk situation, the individual chooses between repertoires of effective or ineffective coping responses (Marlatt & Gordon, 1985). Choosing effective coping skills leads to increased self-efficacy and reduced chance of repeating old patterns. On the other hand, choosing ineffective coping responses leads to decreased self-efficacy, lapses, abstinence violation effects, and performance of old patterns of behavior. Lifestyle imbalances (e.g., lack of sleep) or stress, environmental stimuli, and "apparently irrelevant decisions" are viewed as antecedents of high-risk situations and lapse, whereas outcome expectancies and the abstinence violation effect are thought to contribute to relapses. Initially conceptualized as a repeatable linear process, the model was recently reconceptualized as a dynamic process with coping skills, cognitions, cravings, affect, and behaviors interacting through feedback loops (Witkiewitz & Marlatt, 2004).

Despite the fact that hypothesized constructs were primarily developed to describe the behaviors of individuals trying to change alcohol use and other addictive behaviors, interventions designed using the model have improved dieting behaviors (Kirkley & Fisher,

1988), physical activity (Belisle, Roskies, & Levesque, 1987), and smoking behaviors (O'Connell & Martin, 1987). For adolescent brace-wearing, the RP model may help conceptualize situations in which the adolescent is at high risk for removing the brace when the stimuli are identified as physiological responses (e.g., pain), affect (e.g., anxiety), situational (e.g., playground), cognitive (e.g., verbal behaviors), or social (e.g., peers). However, similar to the other cognitive models, RP ascribes a significant proportion of the variance in prediction to a measure of self-efficacy rather than direct measures of event variables and responses. Doing so reduces the utility of the model to assess variables that contribute to the high risk situations.

Critique of Cognitive Models

Although the models described thus far have hypothesized that cognitive components are important for individuals' adherence behaviors and have demonstrated empirical support, general criticisms exist concerning the stability, clarity, and completeness of the models. For example, the influences of perceived vulnerability and threat on increasing adherence behaviors appears unstable in the HBM, given that findings showed higher adherence to be associated with reduced vulnerability and threat (Bond et al., 1992; Janz & Becker, 1984). Likely, the findings are due to the effects adherence has on reducing threat and perceived vulnerability. For example, when person is taking a medication for high blood pressure as prescribed, he or she may feel less likely to suffer a heart attack or stroke as a result of the high blood pressure. Conversely for some individuals, low adherence rates may increase the perceived threat from the disease and the benefits perceived from the regimen without affecting the actual adherence behaviors. Furthermore, the HBM may not have completely accounted for biases that may also interfere with perception. For example,

individuals and especially adolescents who are more prone to the optimistic bias may underestimate their own risk, thus affecting the vulnerability and severity constructs (Rapoff, 1999). Likewise, adolescents may underestimate their vulnerability for curve progression and contrary to the hypothesized model, may be less likely to identify perceived vulnerability and severity as predictors of brace-wearing. This may account for studies showing less influence of perceived severity when preventative behaviors were examined than when sick role behaviors were examined (85% and 36% respectively; Janz & Becker, 1984). These findings also highlight the importance of the individual's actual experiences with the illness that are not explicitly accounted for by the model.

Models that measure intention, such as the TPB, do not explain the difference between the intention and the behavior and furthermore, intentions are not clearly defined. Since the correlation between intention and behavior is altered by their proximal relationship (Godin & Kok, 1996), the influence on behavior of the variables that increase intentions cannot be assumed to be linear or stable. Another criticism is that verbalizing intentions may have a past reinforcement history that differs from actual intention and, hence, verbalizing intent can not be assumed to be synonymous with the actual intent (Guerin, 1997; Rapoff, 1999). The difference between intended brace-wearing and actual brace-wearing has not been directly investigated, but may be inferred from a study that indicated that even when adolescents negotiated the duration that they would wear their brace, adherence rates did not improve (Takemitsu et al., 2004).

In fact, most of the cognitive models are limited to attitudes and beliefs. However, other influences such as social contingencies and physiological factors need to be considered in order for the models to be complete enough to understand adherence behaviors, such as

adolescent brace-wearing (Rapoff, 1999). For example, the TTM's predictions become circular when membership in one stage is simply defined by the individual's intentions toward the next stages, which limits the stages to simply categorizing behaviors for planning intervention approaches. Interestingly similar to behavioral theories, among several other variables investigated, it was the change in value of the response or behavior (i.e., pro versus con) that reliably predicted initiation and adherence to the new behaviors and progress through the stages (Prochaska & Velicer, 1997). The model also posits that movement through the stages is dynamic, suggesting that in order to capture a stable measure of change behaviors, the reinforcement value of new behavior should be measured over time.

Even if self-efficacy was not originally included in the initial conceptualizations of the models, all of the models described above have come to include self-efficacy as an important variable, yet self-efficacy as an independent cause of behavior has been repeatedly criticized (Hawkins, 1996). Self-efficacy is conceptualized as the belief that one has skills and can effectively use the skills in a specific situation to accomplish a desired behavior (Bandura, 1977). Self-efficacy was hypothesized as a causal factor for adherence behavior because performance feedback was found to alter the participants' self-beliefs in the effectiveness of their efforts (Bandura & Locke, 2003) and self-efficacy was found to correlate positively with adherence behaviors (Strecher, DeVellis, Becker, & Rosenstock, 1986).

In contrast, it can be argued that the participants were given information on their performance that altered their prediction of future performances and that self-efficacy is only an index of the individual's summation of various past performances (Hawkins, 1996). Furthermore, other variables, such as bogus feedback, mood, fatigue, and drug effects also

situationally alter self-efficacy in the same manner as they alter behaviors. The functional dependency of self-efficacy is not enough to determine a causal relationship, but the ability of self-efficacy to influence behavior independently and directly must also be demonstrated. In other words, self-efficacy beliefs are cognitive behaviors or something people do as a result of their prior performance. The environmental factors that influence self-efficacy also influence the behavior directly and may be better identified as the cause.

In light of the above critique, behavior analytic models may contribute to better understanding of adherence behaviors through improved power of prediction. For example, analyzing the antecedent stimuli or establishing operations of specific situations rather than intent to wear the brace could identify the variables that may underlie adolescents' decisions whether or not to wear their brace. Doing so would provide information about situational factors that then might be amenable to change. Next is a discussion of the Behavioral Analytic models and how its constructs explain brace-wearing behaviors that led to the decision to use proximal measures of individual events associated with whether the adolescent wore their brace at the time. This required innovative techniques to assess the environmental, interpersonal, and intrapersonal variables proximal to the events.

Behavior Analytic Model

In behavior analytic models, external and internal environments influence the form and frequencies of adherence behaviors. The frequency of actually performing specified behaviors is generally conceptualized as the dependent variable influenced by contingency histories and associated stimuli. The antecedent stimuli may be external, such as a posted reminder, or internal, such as pain sensations. Several principles are involved in the acquisition and maintenance of behaviors, but the following discussion will focus on

establishing operations, schedules of reinforcement, differential reinforcement, extinction, rule-governance, and generalization and their applications with respect to adherence behaviors.

Establishing operations. Establishing operations influence the reinforcement function of the reinforcer. As a result, a behavior which previously was followed by a reinforcer, becomes more likely in future (Michael, 1982). For example, a state of food deprivation would increase the frequency of responses to gain food reinforcers in contrast to the rate observable when satiated. Since the establishing operation appears to increase or decrease behaviors by increasing or decreasing the effectiveness of a reinforcer or punisher, it has been viewed as providing the motivating function or motivation (Laraway, Snycerski, Michael, & Poling, 2003). Establishing operations differ from discriminative stimuli in that the former provide the motivation for the reinforcer and the latter provide the signal that the reinforcer is available. Moreover, establishing operations regularly occur and several may be present simultaneously which may establish the motivation for different reinforcers. For example, as discomfort increases, the likelihood of removing the brace increases, even in the presence of gains in health benefits for wearing the brace. As a result, altering establishing operations is effective for altering behaviors. For example, removing pain by properly fitting the brace would remove the motivation for removing the brace and increase the likelihood that the motivation to gain the associated health benefits would produce increased brace-wearing behaviors. Also, it is notable that the same response may obtain different reinforcers in different situations (Pierce & Epling, 1999). For example, removing the brace could function in one situation to attain the positive reinforcement of social approval and in another situation as negative reinforcement to remove a painful stimulus. To summarize,

establishing operations increase or decrease the likelihood of that one behavior over another in any given situation by influencing the motivational value of the reinforcer. Therefore, examining the establishing operations and discriminative stimuli in a situation would provide information concerning modifiable variables that underline an individual's intentions.

Schedules of reinforcement. Another set of principles that affect the rate or likelihood of a response occurring are the characteristics of the reinforcer. Schedules of reinforcement differentially affect the rate of learning a new behavior, patterns of responding, and the resistance of that behavior to extinction once reinforcement is removed (Pierce & Epling, 1999).

Continuous rates of reinforcement allow for rapid acquisition of new behaviors, but they are difficult to maintain and extinction occurs rapidly once reinforcement is removed (Ferster & Skinner, 1957; Pierce & Epling, 1999). Drug taking and cigarette smoking behaviors deliver reinforcers at a continuous rate when aversive withdrawal effects are removed or avoided and when positive physical or emotional sensations are experienced. Similarly, discomfort would be reliably removed or avoided when the adolescent removed his or her brace.

The delivery of reinforcers in fixed ratios or after a certain number of responses is emitted produces a pause and run pattern (Ferster & Skinner, 1957; Pierce & Epling, 1999). Because the organism is not reinforced for the next occurrence directly after being reinforced, responding is unlikely until the establishing operations increase the motivation for the reinforcement and then the responses are rapid in order to maximize the likelihood of attaining the reinforcer. This effect could be responsible for the difficulties some individuals

have when attempting to initiate new behaviors and may be corrected by also reinforcing the initial responses. Therefore, the long-term health benefits may not increase the immediate or initial brace-wearing. However, this is contrary to findings that suggest that brace-wearing reduces over time.

The delivery of reinforcers in a fixed interval or after a certain time period has passed produces a significant drop in response rates in the middle of the interval and produces a "scalloped" pattern of behaving, since the organism gains nothing from increasing the rate of responding initially but increases responding near the end of the interval (Ferster & Skinner, 1957; Pierce & Epling, 1999). Unfortunately, when intervals are predetermined, such as scheduled office visits to check on the scoliosis, and reinforcement by the physician is contingent on current behavior, the likelihood of an inconsistent response pattern is increased, which is often the case when patients' behaviors are reinforced *only* during office visits. In addition, if the patient is asked about current or recent adherence behaviors, the temporarily increased adherence rate, which increased in anticipation of the scheduled office visit may inflate the self-report. In contrast, increases in avoidance behaviors may increase substantially immediately prior to an expected event in which the avoidance (or escape) had been reinforced. For example, removing the brace early to avoid embarrassing questions in the locker room would become more likely as the time for gym class approached, if doing so resulted consistently in avoiding questions at that time. However, the adolescent's anxiety about the situation may be low at time periods more distant from the anxiety producing event. For these reasons, continuous and proximal measures of mood and distress concerning events are preferred.

Varying the ratio or interval of responding produces steady rates of responding that are resistant to extinction in most circumstances for wanted behaviors but become problematic for unwanted behaviors (Ferster & Skinner, 1957; Pierce & Epling, 1999). Unexpected phone calls that praise a patient for adherence behaviors or a parent periodically praising their adolescent for brace-wearing can be hypothesized to steadily increase the behaviors and decrease the likelihood of non-adherence in the future. Similarly, high rates of avoidance, such as not wearing a brace, may be maintained if aversive consequence were experienced at infrequent but unpredictable or variable rates. For this reason, examining only the observable variables associated with the actual aversive event may not provide as clear of a picture as including assessments of the individual's anticipation of events. Therefore, assessing mood and cognitive behaviors (i.e., self-report of the reasons for removing brace) may provide information about the adolescents' anticipation or anxiety over brace-wearing in future situations.

Matching law. Although the schedules of reinforcement suggest that any behavior can eventually be increased in natural environments, often several establishing operations may be continuously present and the individual is forced to make choices about responses. How an organism determines the "best" response for the most highly valued and likely reinforcer is mathematically represented in an equation called the *matching law*. The matching law describes choices about responses as a function of rate (R), duration (D), quality (Q), delay (L), bias (b), and sensitivity (a) for the delivery of reinforcement (R) that have been shown to collectively increase or decrease the choice of the associated behavior (Baum, 1974; Herrnstein, 1961; Pierce & Epling, 1999). The ratio of two behaviors (B), B_1/B_2, is equal to the ratio of reinforcement, R_1/R_2, and the relative rate of each reinforcer is

dependent on the collective values, $[b(RDQ_1)^a/L] / [b(RDQ_1)^a/L + b(RDQ_2)^a/L]$. Response costs and punishers also follow the matching law and are subtracted from the numerator of the formula.

The matching law equation has three important implications. First, increasing the reinforcement rate increases the behavior rate, yet the rate is modified by the relative rate of other responses. For this reason, the target behavior, such as brace-wearing and taking medication, must be viewed as a function of the differential reinforcement of alternative behaviors (DRA), high rates of behavior (DRH), or all other behaviors (DRO) and the reinforcement values of competing behaviors that have been put on extinction to reduce their relative value (Bouton, 2000; Pierce & Epling, 1999). Second, shortening the delivery time of the reinforcer can increase the rate of behavior; therefore, immediate reinforcers have a higher relative rate than delayed reinforcers even when their apparent value is less. Conversely, previously pairing a stimulus that can be delivered immediately with a delayed reinforcer, and then delivering the paired stimulus for the response can increase the rate of the behavior, because it acquires the value of the delayed reinforcer while reducing the latency of reinforcement; this is the general principle for token economies. Third, a response is not replaced by another response, but the relative rate of the response can only be increased in relation to another response, suggesting that a response can never have a 100% or a 0% relative rate. Importantly, the relative relationships provide that one previously learned behavior may be chosen over a new behavior, especially if the situation or stimuli are similar to conditions in which the previously learned behavior was reinforced but novel and dissimilar to situations in which the new behavior has been reinforced. In addition, Bouton (2000) demonstrated that the stimuli associated with the reinforcement of the

behavior are generalized more readily than stimuli associated with extinction. In other words, even though removing the brace to escape perceived social ridicule may readily generalize to all public situations because the perceived possibility of reinforcement is high, when the relative reinforcement is put on extinction in one situation, reinforcement values may remain high in the previously generalized situations.

The matching law provides a good model for understanding the effects of the decision-maker's learning history of adherence behaviors, especially in environments in which reinforcement is relatively lean, and why behaviors that improve health in the long-term (e.g., exercising) are frequently forsaken for escaping aversion (e.g., not exercising) in the short-term. Likewise, adolescents may continue to remove their brace in situations similar to those in which they were ridiculed just once, despite the long-term health benefits of wearing the brace. Removing or not wearing their brace generally provides valuable and immediate reinforcement from avoiding negative social situations, removing discomfort, or allowing for activity participation. Conversely, wearing the brace may allow them to avoid discord with their parents in the short-term, and in the long-term, maintain their posture and health and avoid surgery. Although much of human behavior is similar to animal models, humans behave differently and commit fallacies, such as developing irrational "beliefs" that are due to verbal behaviors and complex relational frames used to organize verbal information (Fantino, 1998).

Verbal behavior. Rule-governed behavior is one type of verbal behavior thought to be the source of some irrational beliefs and important in predicting adherence behaviors. Rule-governed behaviors are controlled by intra- or inter-personal verbal antecedents (i.e., instructions, advice, maxims, and laws). Functioning as discriminative stimuli, these verbal

antecedents specify the contingencies of the behavior (Catania, 1995; Skinner, 1969). As a result, the following of instructions and the following of what is contained in the instructions are both made more or less probable by the likelihood of valued reinforcements. Furthermore, verbal instructions can influence the temporal schedule of performance and the control of previously learned contingency relationships by either changing the range of responding options or by establishing additional social contingencies (Hayes & Hayes, 1992). These relationships further highlight the value in assessing intrapersonal behaviors associated with important events. For example, when strangers frequently ask about the brace, the belief that wearing the brace is obvious and unusual is reinforced, but may be mitigated by supportive reassurances and reminders (often by family and supportive friends) that wearing the brace will be associated with future positive consequences in the long term (i.e, distal reinforcer) .

Equally important, verbal behaviors require a system of symbolic references in order to understand the meanings of words. Stimulus equivalence posits that learning the reflexivity, symmetry, transitivity, and equivalence relations between words and the original stimuli through reinforcement contingencies begins when humans are very young and continues lifelong (Sidman, 1971, 1994). More recently the process has been expanded to explain Relational-Frame networks that not only transfer responding between equivalent relationships, but also generalize responses based on opposite and greater/less interrelationships and emphasize the contextual cues and the relationships between frames (Barnes, 1994; Hayes & Hayes, 1992; Steele & Hayes, 1991). Generalized operant responding has been shown to be sensitive to feedback and increased relational responding when the feedback accurately and specifically represented performance on trained

equivalence tasks (Healy, Barnes, & Smeets, 1998). Conversely, participants appeared to generate alternative response patterns to the learned relations when the feedback was inconsistent with their performance. Thus, in the absence of specific reinforcement for new attitudes and beliefs, individuals may be more likely to renew previously learned and sometimes dysfunctional attitudes and beliefs systems. For these reasons, basing feedback to patients on accurate adherence rates would be important for maintenance of new health beliefs behaviors.

Developmental Aspects of Adolescent Adherence

By their nature, several behavior contingencies change as adolescents get older, so the influence of age on adherence is explored below. Changes in the influence of age over time may in part be explained by constructs within behavioral analytic models. These changes were considered in the choice of and modification of assessment tools for the current study.Therefore, before this section is concluded, a discussion of the influence of age on adherence is warranted.

Adolescents display unique patterns of adherence behaviors, likely the result of changing reinforcement values. As a group, adolescents are less adherent than adults or children (DiMatteo, 2004; Shaw, 2001). Contrary to the Health Belief Model, some findings suggest that higher perceived threat actually reduced adolescents' adherence behaviors even when the benefits were high (Bond et al., 1992) and they had more knowledge of disease (McQuaid, Kopel, Klein, & Fritz, 2003). In addition, older age and greater disease severity were related to more barriers to regimen adherence for adolescents (Logan, Zelikovsky, Labay, & Spergel, 2003). Whereas adherence rates of adult men and women do not usually differ significantly, female adolescents tend to adhere more than males (DiMatteo, 2004;

Yrjonen et al., 2007). Meanwhile, older adolescents perceived their family members to provide less support than did younger adolescents, which may account for some of the reductions in adolescent adherence behaviors (La Greca & Bearman, 2002). These findings suggest that adolescents deal differently with the stressors of the threats of chronic illness and barriers to adherence than younger children or adults.

Despite the fact that adolescent developmental changes have often been described using stage models and cognitive variables, the findings above can also be better understood in terms of behavioral contingencies. Non-adherence, which provides negative reinforcement by removing or avoiding stimuli associated with the disease, may become more likely with the increase in barriers and stressors, including the stress resulting from gaining more knowledge of the threat of the disease. For example, adolescents who are not effectively wearing their brace may actually wear their brace even less frequently after finding out their curve is increasing. Non-adherence when faced with more severe consequences is not unlike Sidman's (1989) conceptualization of the tendency to increase negatively reinforced escape and avoidance behaviors, such as dropping out when faced with continuous or severe aversive situations.

Environmental contingencies change as adolescents spend more time away from their parents and develop separate identities and relationships with others. In addition to Rapport (1999) and La Greca (2002), who suggest that greater parental supervision of adherence behaviors is related to improved adherence behaviors, De Civita and colleagues (2004) also assert that parental involvement is a critical variable to consider. As adolescents get older, schedules of reinforcement become leaner as parents provide less supervision and thereby less reinforcement (Pierce & Epling, 1999), a phenomenon which may account for

the temporary reductions in adherence behaviors until adulthood when self-reinforcement becomes more likely. According to the matching law, the reduction in the rate of reinforcement would reduce the likelihood of the target behavior, therefore increasing the likelihood of competing behaviors. The effect would be intensified if the schedules of reinforcement become too lean, as may be the case with families experiencing other difficulties (Reid, McGrath, & Lang, 2005). At the same time, new opportunities for reinforcement become available, such as for conformity, new role boundaries, social status, athletic competence, peer group identification, and decision-making (Newman & Newman, 1987), and new matching law equations would adjust to accommodate the new experiences. However, initially the lack of experience with the new contingencies may contribute to poor risk assessments (Shaw, 2001) until the adolescent has enough experience to more accurately predict the possible outcomes. Additionally, Shaw argues that non-adherence may also function to gain previously experienced supports from others. These differences in contingencies for adolescents highlight the need to assess environmental, interpersonal, an intrapersonal potential determinants of adherence while the adolescents are in treatment and not after treatment when contingencies may have changed.

Summary

Thus far, the behavioral analytic model appears to explain adherence behaviors more completely and clearly than the models that rely on cognitive beliefs. The Health Belief Model and Theory of Planned Behavior model rely on reported intentions that lack clear connections with actual behaviors. The Social Cognitive Theory, Transtheoretical Model, Self-Management Model, and Relapse Prevention Model rely heavily on self-efficacy, which may be summation of prior events and only indirectly predicts current adherence

behavior. Behavior analytic models that examine the direct influence of variables on behaviors in differing situations are capable of providing a more comprehensive understanding of the predictors of adherence in general and, specifically, adolescent brace-wearing.

An individual's adherence behaviors may be best predicted and influenced through the understanding and manipulation of behavioral variables. Establishing operations illustrate the manner in which stimuli function to increase adherence behaviors or reduce behaviors even when the value for alternative responses have been established. Schedules of reinforcement and the matching law provide a framework for conceptualizing how individuals choose between competing options but sometimes seem to make irrational choices and suggest how to increase the effectiveness of reinforcers delivered during interventions. Rule-governance, stimulus equivalence, and relational frames provide behavioral explanations for the cognitions, including self-efficacy, that provide a richer understanding of the influences of instructions, feedback, and thinking behaviors and how they may alter overt contingency relationships. Furthermore, contingency relationships provide for the conceptualization that changing the environment and contingencies dynamically influences adherence behaviors, especially for adolescents. Accordingly, behavioral theories more fully explain why past or current adherence behaviors best predict future behaviors (Sherbourne et al., 1992).

Traditionally, behavioral variables have been assessed through direct observation, which would not be feasible for adolescents in their natural environments. Previous assessment methods used to assess psychosocial variables associated with adherence may not be applicable to assess the environmental, interpersonal, or intrapersonal variables

associated with brace-wearing and behavioral analytic models. What follows is a review of assessment considerations that went into the design of the current study, and into the format of the assessments actually used, in particular the behaviorally oriented assessment tools.

Assessing Adherence Behaviors

Currently, the effectiveness of part-time versus full-time brace-wearing for AIS remains controversial and may be better resolved when the actual brace-wearing behaviors are accurately measured. When assessing patients' adherence behaviors, we are asking two questions. The first question is whether patients are performing enough of the desired behaviors to benefit from the treatment or optimize their health. The second is which internal or external events increase or decrease the likelihood that patients will perform the desired behaviors. The focus of the current investigation is the latter. The following section will (a) show why it is problematic to use psychosocial questionnaires that assess global cognitive factors that are distal in time from the adherence behaviors without also assessing the contextual situations that may contribute to the patient's perceptions; (b) demonstrate why cross-sectional and some prospective group designs may not be sensitive enough to identify predictors that contribute to the decisions about actual adherence behaviors; and (c) thereby make a case that examining multiple assessments of actual events proximal in time to their occurrence, including objective measures of actual adherence, for each individual as well as for the entire sample may provide a better understanding of the predictors of adherence behaviors.

Although a meta-analysis concluded that relationships between adherence and medical outcomes were related to several methodological factors including the sensitivity or quality of the adherence assessment instrument (DiMatteo et al., 2002), when choosing the

source of information (e.g., self-report, other-report, chart review, or objective measures), investigators often balance feasibility against accuracy of the various types of assessment. Self-reports gathered by interviews and questionnaires are the most common forms of assessment because they are the easiest to use, least expensive, and the participant has access to all the behaviors. Paper-and-pencil questionnaires can be administered in laboratories or in the participant's home and require very little administrator involvement. If the participant is assured that confidentiality is protected, bias due to social desirability may be reduced. However, questionnaires rely on the participant's understanding of the content, order of the questions, and response choices. Self-report questionnaires have commonly been used in the investigations of adherence to brace-wearing to assess the reasons adolescents did not wear their braces and psychological factors associated with brace-wearing (Andersen et al., 2002; Climent, Reig, Sanchez, & Roda, 1995; Lindeman & Behm, 1999; Masso, Meeropol, & Lennon, 2002; Morton et al., 2008; Nicholson et al., 2003; Wickers et al., 1977)

Alternatively, interviews that use more open-ended questions minimize the possibility of selection bias, which may occur when potential options are provided (Marlatt, 1996). Interviews can improve the quality of information gathered when investigators are able to assist participants with understanding confusing questions and ask for more information to clarify answers. However, interviews rely on and make significant time demands on investigators for training in and administering the interviews and interpreting/coding the resulting responses. In the process of coding responses, inter-rater reliability could become especially problematic when responses appear to fall into multiple categories, such as an argument with a spouse, which may be considered both a

interpersonal conflict and a negative mood (Donovan, 1996). When investigating adherence to brace-wearing, inter-rater reliability was not even reported in several studies when adolescents and/or their families were interviewed to assess adherence rates and associated psychological factors (Climent et al., 1995; DiRaimondo & Green, 1988; Karol, 2001; Korovessis et al., 2007; Lindeman & Behm, 1999; Vandal et al., 1999).

Importantly, interviews may also increase the tendency for demand effects and social desirability to bias participants' answers (Rapoff, 1999). Social desirability and demand biases increase when participants perceive that their responses may lead to other consequences and may greatly influence patient reports to their physicians or nurses. For example, when using interviews, Dunbar-Jacobs and colleagues (1992) identified just 7% of participants as not being adherent, but electronic monitoring indicated that 54% were not adherent, suggesting they missed 94% of non-adherent patients (as cited in Dunbar-Jacobs et al., 1995). Nevertheless several of the investigations of adolescent brace-wearing relied on verbal reports to medical professionals (Bowen et al., 2001; Emans, Kaelin, Bancel, Hall, & Miller, 1986; Gurnham, 1983; Karol, 2001; Katz & Durrani, 2001; Takemitsu et al., 2004; Wickers et al., 1977; Wiley et al., 2000; Yrjonen et al., 2007). According to Rapoff (1999) and Dunbar-Jacobs et al. (1992), using verbal reports to medical professionals may have lead to over-reporting of adherence and may have led to incorrect inferences concerning the variables associated with brace-wearing for these investigations.

Despite biases due to social desirability and problems respondents might have simply understanding paper and pencil questions, one of the principal reasons self-reports may be inaccurate is that they often rely on participants' ability to recall events. When reporting the frequency of frequently occurring behaviors, participants are more likely to estimate the rate

of the behavior rather than use recall and counting strategies (Menon, 1993). Memory for chronological events depends on active and repeated reconstruction and is more related to our knowledge of time patterns, which differs from our memory of event details (Friedman, 1993). Furthermore, inaccuracy and use of heuristics increases with the longer the time period the participants are requested to recall. Methods have been developed to reduce the recall length, but even retrospective daily reports have reflected recency and saliency heuristic biases (Marco, Neale, Schwartz, Shiffman, & Stone, 1999). Thus asking the participants about whether they wore their brace and what variables were associated with brace-wearing immediately after events would produce the most reliable results. Despite this, the majority of investigations of brace-wearing did not report the interval the adolescent was asked to recall, but for many it can be assumed to be the entire treatment period (Bowen et al., 2001; Climent et al., 1995; Edgar, 1998; Lindeman & Behm, 1999; Vandal et al., 1999) or the time since the last office visit, which may vary from one to six months (Emans et al., 1986; Gurnham, 1983; Karol, 2001; Katz & Durrani, 2001; Nicholson et al., 2003; Takemitsu et al., 2004; Wickers et al., 1977; Wiley et al., 2000). Confidence in the accuracy of variables associated with brace-wearing is also reduced for investigations conducted after treatment was completed (DiRaimondo & Green, 1988), two years later (Masso et al., 2002), and up to eight years later (Andersen et al., 2002).

Similar methods used to collect adherence information from parents or significant others in the environment are also not error-free. Confederate reports are beneficial when the participant is unable to report their behavior (e.g., too young), or when verifying the reliability of information by gathering responses from multiple sources. On the other hand, confederates may not be privy to all the behaviors of the participant and may have their own

difficulties with adherence behaviors, reasons to misrepresent information, difficulties recalling events, and levels of understanding of the intervention requirements. For example, more than 70% of parents were unable to report on their adolescents' diabetes-related regimen behaviors (Bond et al., 1992). With respect to scoliosis, although some studies mentioned that a parent supplied information about adherence (Climent et al., 1995; Edgar, 1998; Katz & Durrani, 2001), only one of the investigations reported directly assessing the parents' ratings of their adolescents' brace-wearing (Korovessis et al., 2007). However, parents of adolescents cannot observe their child while they are at school or certain activities, such as parties, and parents' direct observations of their child likely lessen as the adolescent ages and becomes increasingly independent.

Other frequently used sources of information concerning brace-wearing are the medical provider or chart records (Bowen et al., 2001; Emans et al., 1986; Gurnham, 1983; Karol, 2001; Katz & Durrani, 2001; Wiley et al., 2000; Yrjonen et al., 2007). Chart records may provide accurate information on participants' history, such as assays results, medical utilization, pharmacy refills, and appointment attendance. However, medical professionals do not have direct knowledge of the participants' behaviors and may construct their judgments based on health/disease status, participant or family characteristics, the participants' interest or attention, direct questioning of participant, checking prescription refills, and in-office demonstrations of behaviors (Rapoff, 1999). Furthermore, medical professionals' judgments often reflect biases from anchoring new information to initial judgments, illusionary correlations of events, and overconfidence (Meehl, 1957; Rock, Bransford, Maisto, & Morey, 1987). Meanwhile, medical professionals demonstrated greater accuracy when identifying participants who are adherent than when identifying those who

are non-adherent (Finney, Hook, Friman, Rapoff, & Christophersen, 1993). In other words, they are more likely to make false positive judgments and assume that adolescents were wearing their brace when they are not. The inaccuracy of physicians' judgments of adherence has been demonstrated when a comparison with objective measures of brace-wearing indicated the physicians inaccurately identified adolescents that were adherent 29% of the time (Edgar, 1998). Therefore, even though self-reports can be problematic, parental and medical provider reports or charts may not improve the accuracy of self-reported information.

In general, objective measures such as assays, pill counts, and electronic monitors seem intuitively to be an accurate measure of drug levels, metabolic response, or adherence behaviors, but they are not without liabilities. With respect to determining brace-wearing patterns in scoliosis, electronic monitors have also been used to objectively measure body temperature, strap tension, and pressure (see Table 2). Reliability was reported to be "near perfect" when recorded events were triggered by strap tension changes when the brace was put on or taken off (Vandal et al., 1999), 98% when temperature was sampled at 10-minute intervals (Takemitsu et al., 2004), and 90% when temperature was sampled at 16-minute intervals (Nicholson et al., 2003). When pressure was sampled at 1-minute intervals, correlations with self-reported brace-wear during testing were greater than .99 (Havey et al., 2002), and when temperature was sampled at 15-minute intervals (Morton et al., 2008) More importantly, the actual average adherence rates, found to range from 33% to 75%, were substantially less (at least by 150%) than adherence self-reported by adolescents to range from 74% to 89% (Takemitsu et al., 2004; Nicholson et al., 2003; Vandal et al., 1999; Morton et al., 2008). Measuring pressure at the corrective or "apex" points of the brace

added the information that 30% of the time the adolescents wore their brace too loosely to provide benefits (Lou et al., 2004), but pressure readings can vary 10% to 60% during activities (Lou et al., 2002). Consequently, Havey demonstrated that due to the variability in pressure at different locations on the brace, concordance between at least two sensors might be necessary. Measuring brace temperature on the inside surface can also be problematic when outside temperatures approach skin temperature ($M = 91^{o}$ F, SD = 2^{o} F; Nicholson et al., 2003). Similar to other electronic devices, brace monitors reportedly fail because of electrostatic buildup and humidity (Vandal et al., 1999), temperature-related battery failure, or simply being disconnected (Havey et al., 2002).

In conclusion, electronic measures of brace-wearing may provide the most accurate assessment of the duration and patterns of actual brace-wearing. Furthermore, because of the possible variations in readings due to movement and temperature, using two different types of sensors may increase reliability in the measures of brace-wearing. However, electronic monitoring does not provide information about situational or intrapersonal variables connected to adherence behaviors, which may be best assessed by self-reported instruments that are developed specifically to improve recall and control for biases.

Table 2

Reliability and Objective Measure of Adolescent Brace Wearing: Pressure, Temperature, and Strap Tension

First Author, year	Reported adherence	Objective adherence	Reliability with preliminary diary information*	Sampling method	Interval	Duration
Pressure						
Lou, 2006		57%				
Lou, 2006		34% not worn, 62% at or above target pressure		Sampled	1 minute	2 weeks
Lou, 2004		70% not worn; 40% at or above target pressure		Sampled	1 minute	3 to 14 days
Lou, 2002		62%		Sampled	1 minute	3 to 14 days
Havey, 2002			R^2 = .998 correlation of events	Sampled	1 minute	7 days
Temperature						
Morton, 2008	74%	46%	99.9%	Sampled	15 minutes	6 - 11 months
Hellfenstein, 2006		67.5%		Sampled	2 minutes	5.4 weeks (SD 3.1)
Takemitsu, 2004	85%	75%	98% time agreement	Sampled	10 minutes	4 to 31 months
Nicholson, 2003	89%	65%	90% time agreement R^2 = .998 correlation of events	Sampled	16 minutes	$\leq$ 88 days
Edgar, 1998		68%		Cumulative time $\geq$ 30° C	N/A	4 months to 3 years
Strap tension						
Vandal, 1999	88%	33%	Near perfect	On/off event	N/A	3 months

*Prior to major study

Assessing Psychosocial Subjective Predictors of Brace-wearing

Assessing the situational and psychosocial factors associated with adherence and, specifically, brace-wearing would require asking the adolescent about the presence of antecedents and the adolescent's perceptions of these antecedents. However, to date the

psychosocial factors associated with brace-wearing have been measured using unvalidated investigator-constructed instruments (Andersen et al., 2002; Vandal et al., 1999) or general (i.e., not disease-specific) instruments such as intelligence or self-esteem ratings (Lindeman & Behm, 1999; Masso et al., 2002; Wickers et al., 1977) or quality of life ratings (Climent et al., 1995; Lindeman & Behm, 1999; Morton et al., 2008) and beliefs (Morton et al., 2008). The state of the literature points to the need for the development of a questionnaire that assesses the situational, interpersonal, and intrapersonal variables associated with brace-wearing.

Just as adherence behaviors have been assessed in a variety of ways, so too, in the absence of scoliosis-specific instruments, the psychosocial variables hypothesized to predict brace adherence behaviors continue to be assessed in a variety of ways with the most universal forms remaining retrospective self-reports, such as questionnaires or interview formats. In addition to problematic biases and heuristics in retrospective reports, the psychometrics of the assessment methods used to investigate the common models are questionable when the instruments are frequently modified depending on the type of behavior and disease investigated (i.e., Health Belief Model), when the realism of the situation is altered (i.e., Theory of Planned Behavior), when constructs are intercorrelated (i.e., Transtheoretical Model), or when research groups vary taxometrics (i.e., Relapse Prevention Model). For these reasons, Rapoff (1999) recommended investigating both disease-specific and general health beliefs but points out that few good measures of general health beliefs currently exist.

For example, in order to capture complex idiographic information, Relapse Prevention investigators have used a structured interview, the Comprehensive Drinking

Profile, or a version adapted for other smoking and binge-eating populations (Marlatt, 1996; O'Connell & Martin, 1987). On the basis of theorizing that past behaviors were predictive of future behaviors, participants were asked about why they drink or have relapsed in the past. The open-ended questions were designed to minimize biasing recall by triggering selective responses but require the raters to interpret and classify responses into taxonomic categories. Using Marlatt's categories of intrapersonal-environmental and interpersonal determinants, inter-rater reliability was high in the original investigations; however, multi-site replications found more variability and concluded that more situations and reasons that could co-occur should be assessed (Lowman, Allen, & Stout, 1996). Curiously, after transforming the categories into questionnaire format, risks associated with relapse clustered into three different categories that seem to represent negative affect, conflict with others, and seeking pleasure instead of the original four constructs (Zywiak, Connors, Maisto, & Westerberg, 1996). The lack of replicability within substance abuse populations reduces the confidence that the constructs would be generalizable to other non-substance abuse populations, such as teens with scoliosis who are prescribed a brace to wear.

In addition, most investigation of the psychosocial variables associated with adherence contact participants either once or at repeated but infrequent intervals. These methods may capture distal causes (i.e., stimuli that are generally related but distant in time from the target behavior) but may not effectively capture proximal causes (i.e., stimuli that are directly related to and close in time to the target behavior). For example, lower ratings of self-efficacy at baseline predicted lapses or short-term return to previous behaviors, but daily reductions in self-efficacy predicted relapses or long-term return to previous behaviors (Shiffman et al., 2000); readiness to change did not directly influence outcomes, but use of

coping skills did (Litt, Kadden, Cooney, & Kabela, 2003). These reported differences between efficacy of proximal and distal reports may be the result of the influence of recall heuristics and hypothetical biases in more distal reports on past events or future intentions.

To summarize, since the reviewed assessment methods for the Health Belief Model, Theory of Planned Behavior, Transtheoretical Model, and Relapse Prevention Model lack generalizability across behaviors and diseases, they do not offer a method that would reliably assess brace-wearing for adolescents. In contrast, the Behavior Analytic model and its related constructs hypothesize that contextual proximal causes may be more predictive and therefore more appropriate to assess daily behaviors, such as brace-wearing. Measurement methods compatible with Behavioral Analytic models are self-monitoring in general, and Ecological Momentary Assessments (EMA; Stone, Kessler, & Haythornthwaite, 1991) and the related Daily Reconstruction Methods (DRM; Kahneman, Krueger, Schkade, Schwarz, & Stone, 2004) in particular. Self-monitoring is not without its liabilities and the type and frequency of data collection needs to be considered.

Self-monitoring

Like other observational methods, self-monitoring methods can record adherence behaviors and situational variables. EMA (Stone et al., 1991) has been used to assess a variety of factors in participants' daily lives. DRM (Kahneman et al., 2004) has recently been developed to collect information about daily events while reducing the burden on participants. Using factors shown to improve other observational methods, self-monitoring, EMA, and DRM methods may provide a more reliable assessment of the contextual variables associated with adolescent brace-wearing. Specifically, the DRM may be unintrusive and collect enough information to allow for robust analyses.

Except under experimental conditions, direct observations by independent raters are rarely used because the methods require considerable time investment by the investigator, raters, and participants. Because participants already have continuous opportunity to observe their own behaviors, self-monitoring is the most frequently used observational method. Observers can record the frequency with which a behavior occurs within a time-period, the onset and duration of behavioral events, and/or the establishing operations (e.g., setting), discriminative stimuli (e.g., significant persons), and consequences of the target behaviors (e.g., escape). The frequency and variability of the target behavior usually determines if the behavior is sampled continuously, momentarily, or during specific intervals, each having their distinct benefits and risks. For example, whole interval recording tends to consistently underestimate and partial interval tends to overestimate the duration of behaviors when compared with continuous sampling (Foster & Cone, 1995). The sampling errors increase with interval duration, but the errors are not seen in fixed-interval momentary sampling. Behavior checklists have also been used to record the occurrence of discrete tasks within more complex tasks and have been successfully used with a pediatric population with asthma (Boccuti, Celano, Geller, & Phillips, 1996). Similarly, adolescents who wear a brace should be capable to providing information about their ongoing behaviors.

An important but often-overlooked concern for the collection of observational data is the reliability of the data collected. Foster and Cone (1995) explain that the observer must be in contact with the behavior, detect change, discriminate target behaviors, and assign the behavior to categories. Thus, the observer should be trained to observe the behavior, discriminate between behaviors, and use the equipment or recording form. Besides social desirability and demand bias mentioned earlier that influence self-reported behaviors, other

participant activities and forgetting to record one's own behaviors can further reduce the accuracy of the reports (Cone, 1999). Therefore, whenever feasible, inter-rater reliabilities should be calculated to verify the reliability of the data. Even though well-established methods exist to calculate interrater reliability in analogue settings, in natural settings sampling the convergent validity between two different raters (e.g., parent and child), between two methods (e.g., diary and electronic monitor), or with a behavioral byproduct (e.g., weight change) may be necessary (Korotitsch & Nelson-Gray, 1999). Therefore, since participants tend to overreport their rates of brace-wearing, electronic monitoring may be necessary to accurately assess the reliability of the participants' reports. Furthermore, self-monitoring has been used as a treatment component because of the high potential for reactivity. However, reducing reactivity can be accomplished by using event sampling methods, recording verbal events, monitoring multiple responses, recording the response after the occurrence (not the intent before), avoiding placing contingencies based on occurrence of the target behavior, and reducing obtrusiveness of recoding device.

Although not new, ecological momentary assessments (EMA) have not been used widely in adherence studies. EMA is a class of assessments that include experience-sampling methods, which randomly record momentary private subjective events, and event recordings. EMA differs from the other objective methods in that it explicitly includes self-reports of behaviors, physiological measures, and subjective experiences (Stone & Shiffman, 2002). EMA may be especially well-suited for measuring adherence behaviors because the behaviors must be performed many times a day and require participants to make multiple decisions each day that may be affected by multiple contextual stimuli. The presence of intra- or interpersonal variables that can be linked to increases or decreases in the behavior

may constitute specific high-risk situations. Furthermore, assuming that each individual has a unique learning history, the relevance and relationships between variables would differ across individuals and may change over time. Instead of relying on accounts of distal past behaviors, hypothetical future behaviors, or generalized beliefs, EMA records current and ongoing behaviors in the participants' natural settings.

Importantly, analysis of EMA data can identify coexisting relationships, temporal or lagged relationships, and patterns of behaviors. For example, in one investigation, stress and activity triggered pain immediately for some participants but triggered pain 30 minutes later in other participants (Geisser, Robinson, & Richardson, 1995). Another investigation showed that even though women recalled using more social methods of coping, their daily coping strategies did not differ from those used by men (Porter et al., 2000). In addition, significant diurnal patterns in pain and fatigue ratings were found for participants with rheumatoid arthritis (Stone, Broderick, Porter, & Kaell, 1997). These findings likely would have been overlooked if assessments relied on participant recall or were measured infrequently. Likewise, the patterns of brace-wearing and the association with the presence of situational (e.g., sports activity), interpersonal (e.g., friend), and intrapersonal (e.g., pain) stimuli could be assessed using EMA.

EMA suffers from many of the same weaknesses as other observational and self-monitoring techniques. Sampling must be considered carefully, since random momentary sampling may misrepresent infrequently-occurring events if they are over- or under-sampled. Some analyses require more than a hundred data points and, since each participant has to provide all the data, each participant must provide a sufficient number of data points. In the meantime, dense collection schedules, lengthy questionnaires, difficult procedures, or

intrusive equipment may overburden participants and increase the likelihood of attrition, missing data, and reactivity. One common method of signaling participants is to use a device, such as a wristwatch, to prompt the participant to complete a paper diary. However, when verified with monitors in one study, adherence to diary completion was only 34%, which was significantly discrepant from the 88% self-reported by participants (Broderick, Schwartz, Shiffman, Hufford, & Stone, 2003). Completing assessments at the appropriate time was increased from 11% to 94% when participants were aware the time they were completing the assessments was being monitored (Stone, Shiffman, Schwartz, Broderick, & Hufford, 2002). Finally, although reactivity has been a concern for self-observations, electronic collection methods do not provide feedback to the participant, and subjective reports of reactivity have not been supported by changes in actual ratings (Aaron, Turner, Mancl, Brister, & Sawchuk, 2005; Stone et al., 2003).

The recently developed Daily Reconstruction Method (Kahneman, Krueger, Schkade, Schwarz, & Stone, 2004) retains the benefits of EMA while reducing the burden on the participants. The method requires participants to first create a list of all the events that occurred in the last 24 hours. Although the method does rely on participant recall, listing events in this manner increases the accuracy of retrospective reports by promoting sequential and parallel retrieval within the memory network (Belli, 1998). Next, the participant answers a series of questions, which, similar to EMA, requires the participant to self-report behaviors, physiological measures, and subjective experiences occurring during each event (Kahneman et al., 2004). Each event constitutes an assessment point, thereby providing several assessments for each day that can be sufficient to permit analyzing variables within and across participants. Furthermore, by assessing all the events during the

period, the DRM reduces the chance of missing events that occur infrequently and might be missed using EMA. Also important is that, as demonstrated by variability within each day in an investigation of well-being, DRM appeared to be successful at limiting recency, saliency, and valence biases that usually affect participants' recall of subjective or emotional events (Kahneman et al., 2004). If the participants are asked to complete the DRM at a convenient time just once during the day, it would be less obtrusive and burdensome for the participant than standard EMA that signals the participants multiple times each or asks them to record events just after they occur. DRM may be especially well-suited for gathering data about daily events for adolescents since signaling devices and completing questionnaires may be very obtrusive in classrooms or during organized activities.

Using objective methods to assess adherence and the DRM to assess proximal environmental, interpersonal, and intrapersonal variables would address several of the methodological issues present in the investigations of adherence for brace-wearing. What follows is a review of the problematic methodological issues in the existing brace-wearing literature and discussion of using single cases designs to provide more complete information concerning the variables that predict the situations in which adolescents would either wear or not wear their brace

Design Issues

The extant investigations of adolescent brace-wearing are plagued by several problematic methodological issues. Because it is not possible to use randomized-controlled treatment designs to investigate brace-wear, studies of adherence must rely on descriptive methods that are flawed in many ways. Cross-sectional and case-controlled designs limit inferences about causation. Not directly assessing psychosocial variables or combining

several variables into one composite limits the ability to make inferences about the unique contribution of each psychosocial variables. Unvalidated or poorly validated assessment methods reduce confidence in the accuracy of the information gathered. Below follows a review of the investigations of adolescent brace-wearing, which are limited by these issues (i.e., cross-sectional retrospective designs, indirect assessment methods, and inadequately validated assessment methods) and thus severely reduce the confidence in their findings.

Case-contolled and cross-sectional designs. The majority of the information in the literature about the antecedents and correlates associated with brace-wearing behaviors is provided by (a) case-controlled designs that divide groups by some criterion (e.g., adherent, non-adherence) and then examine the difference between the groups, and (b) correlational non-experimental designs. Case-controlled designs and correlational designs are most problematic when they are cross-sectional, because without observing the temporal association, inferences about causation are limited (Kazdin, 2003). Nine of the investigations of adolescents' adherence to brace-wearing assessed psychosocial factors using cross-sectional group designs (Andersen et al., 2002; Bowen et al., 2001; Climent et al., 1995; DiRaimondo & Green, 1988; Gurnham, 1983; Korovessis et al., 2007; Lindeman & Behm, 1999; Masso et al., 2002; Wickers et al., 1977). Not only are inferences about causation in cross-sectional design limited, but when groups are studied significant ideographic patterns may be overlooked (Andrykowski, Cordova, McGrath, Sloan, & Kenady, 2000; Gil et al., 2000). Furthermore, when different studies use different cut-off points to define whether the participant was adherent or not, comparisons across studies are complicated if not impossible. For example, comparing one study that defined adherence based on whether the patient returned for future visits (Gurnham, 1983) to one that defined

adherence by wearing the brace over 90% of the time prescribed (DiRaimondo & Green, 1988) would be impossible. In addition to being cross-sectional, some of variables associated with brace-wearing were descriptive (e.g., percentage of participants), making their statistical significance questionable (Andersen et al., 2002; Gurnham, 1983). In order to capture information for more than the one point in time, case-controlled designs are usually retrospective and so plagued by biases, which negatively affect the validity of the studies as shown below.

How timing of assessment affects validity. Because recency and saliency biases negatively affect the accuracy of a participant's recall (Marco et al., 1999; Menon, 1993; Menon, Raghubir, & Schwarz, 1995), as does the longer the time interval that has transpired since the event in question (Friedman, 1993; Menon, 1993), participants' reports may not be accurate: in one study (Andersen et al., 2002), participants had been out of treatment for as many as eight years; in another study adolescents in different treatment groups were assessed two years after treatment (Masso et al., 2002). A third study did not even describe at what point in time the participants were asked to recall their past brace-wearing (Climent et al., 1995). After such long periods of time since treatment, the participants may not have remembered some variables or may have altered the importance of situational variables. Therefore, measures more proximal in time are desirable in the interests of accuracy. In attempts to address some of these problems, some studies used objective measures of adherence in longitudinal designs to more accurately assess adherence rates. However, even these studies used more distal and global and thus indirect assessments of psychosocial variables.

Indirectly assessing unique psychosocial variables. The investigations that objectively measured adherence, although accurate in describing adherence rates and patterns, are nevertheless limited in their ability to assess why the adolescents do not wear their brace. Ten studies used brace monitors and prospective methods to accurately assess adherence patterns and/or analyze the physical outcomes of brace treatment or the utility of monitoring devices for determining actual adherence rates, but did not directly assess psychosocial factors (Edgar, 1998; Emans et al., 1986; Helfenstein et al., 2006; Lou et al., 2002; Lou, Hill, Raso, Mahood, & Moreau, 2006a; Lou et al., 2004; Nicholson et al., 2003; Rahman et al., 2005; Takemitsu et al., 2004; Vandal et al., 1999). A prospective investigation that actually did assess cognitive and attributional variables and objectively measured adherence is nevertheless limited in the ability to determine the unique contribution of each variable (Morton et al., 2008). More specifically, in this study, pretreatment expectation and knowledge about treatment, attitudes toward healthcare professionals, peer and family influences, and beliefs about health self-efficacy were all summed into a single final score for the Brace-Beliefs Questionnaire.

Other validity issues: Inferences derived from some investigations using possibly biased or otherwise inadequately valid adherence assessment methods are further limited. Adolescents may be concerned about the consequences of information they provide to their parents or medical providers. For this reason, the presence of and collaboration with the parent or medical professional during solicitation of information increases the probability of social bias in the adolescents' reports. Even so, one study interviewed the adolescents with their accompanying parent and used their self-report after it was "in agreement" with the parent's report (Climent et al., 1995). Disturbingly, another seven relied on chart reviews

that collapsed reports to professionals during medical visits every three to six months into single indications of the degree of patient adherence (Bowen et al., 2001; Emans et al., 1986; Karol, 2001; Katz & Durrani, 2001; Wickers et al., 1977; Wiley et al., 2000). In these studies, the participants may not have been truthful concerning their brace-wearing in the presence of parents or medical professionals.

Other methodological problems: Making the fewest inferences possible is parsimonious and preferable (Kazdin, 2003; Kerlinger & Lee, 2000); yet investigators in one study (Gurnham, 1983) assumed the stability of the family from whether one or two parents were in the home. This assumption may not hold in all cases, however. For example, a single parent who resides with one or more older relatives may have more resources and support than a young and struggling or conflictual couple. For these reasons, confidence in the accuracy of the results from this study (Gurnham, 1983) is reduced.

In summation, cross-sectional group designs that have been used to assess psychosocial variables associated with brace-wearing predict the behavior of groups, but may not be sensitive enough for investigations into adherence behaviors that may be more individualized and dependant on individual contextual situations. In addition, cross-sectional group designs have a limited number of observation points and generally rely on retrospective recall by the participants, which, as mentioned extensively in the previous section, are prone to a variety of heuristic biases. Although group designs have been the most commonly used method of studying general and global behaviors, an alternative and more preferable approach would be an examination, *within* cases of daily behaviors of individuals as incorporated in the design of the current study.

Single-case Designs

Although self-monitoring data, such as that collected by the DRM, can be collapsed into global indices, importantly DRM data provide the opportunity to examine as many as 14 events daily for each participant (Kahneman et al., 2004), suitable for regression analysis of single-cases. Similar to randomized controlled treatment designs, single-case designs are capable of demonstrating causal relationships and of ruling out threats to validity because the performance of the individual is examined in differing conditions (Kazdin, 2003). The main feature of single-case designs is the continuous assessment of the individual. Multiple measures also allow for the evaluation and control of the stability of performance, thereby reducing the possibility of spurious results. Single-case designs provide sufficient evidence about the relationship between treatment and behaviors that replications across only three participants by two different research groups is adequate to determine that the treatment's efficacy is established (Chambless & Hollon, 1998).

Although traditionally single-subject data have been analyzed using the visual criteria of marked change (Kazdin, 2003), one historical factor that has made single-case designs more useful is the development of computerized software that can handle the vast amounts of data generated by such designs and that can correct for autocorrelation among the repeated measures (Schwartz & Stone, 1998). Data from many computerized devices can now be downloaded directly into statistical programs with minimal translation, with the added advantage of reducing entry errors. Although unobserved constants and heterogeneity within cases can also reduce the accuracy of statistical inferences when multiple measures are examined across grouped observations, current statistical programs can remove their

error variance along with controlling for multiple demographic variables (Mertler & Vannatta, 2002).

In summary, variables proximal in time have been indicated in studies of adolescent brace-wearing as significant reasons for not wearing the brace (Andersen et al., 2002; Nicholson et al., 2003). In addition distal retrospective self-reports of adherence do not correlate well with objective measures of brace-wearing (Nicholson et al., 2003; Takemitsu et al., 2004; Vandal et al., 1999). Therefore, as explained in the "Assessing adherence behaviors" and "Self-monitoring" sections above, DRM single-case designs in combination with objective measures of adherence behaviors may be especially suited to provide reliable support for the influence of psychosocial factors on brace-wearing. It is this combination that was incorporated into the research design of the current study.

Existing DRM methodology lacks reliable and validated instruments that are applicable to measuring psychosocial variables associated with adolescent brace-wearing. This gap has made it necessary to design questionnaires specifically for use witht the DRM in assessing adolescent brace-wear.

In the process of designing new instruments, in addition to expert samples, naïve samples that include representatives from the target group can help identify the appropriateness of questions (Haynes, Richard, & Kubany, 1995). Including information from a representative group in the modification of current instruments may increase the content validity and cultural sensitivity of the instrument, thereby increasing the confidence in the inferences drawn from the results. Thus the present investigation solicited information from a group of representatives from the adolescent population with scoliosis in order to

facilitate identifying variables in their daily lives that are unique and important to assess but may have been overlooked in the literature or by adult experts.

Therefore, as a preliminary phase to the current investigation, a group interview was conducted to provide guidance in selecting event-prompts and inter- and intrapersonal variables to include in the DRM method being adapted for use with adolescents with scoliosis. The group interview procedure and outcomes are described below and indicate steps by which the final version of the DRM was modified to the form used in this study.

Preparatory Investigation for Instrument Development: Group Interview

As noted above, the purpose of the group interview as a preliminary step for the study was to qualitatively gather lists of environmental and internal stimuli that influence brace-wearing for adolescents with idiopathic scoliosis in order to modify the DRM for this project. A group interview was conducted of adolescents with scoliosis to provide information about what makes wearing their brace difficult and what would help them to wear their brace more often.

Methods

Participants. An orthotics technician recruited one group of females adolescents and one group of male adolescents between the ages of 13 and 18, who were currently prescribed an orthopedic brace for idiopathic scoliosis. Any child was excluded if he or she could not obtain parental/caregiver informed consent, or if the child or parent/caregiver could not understand English. The adolescents were grouped by gender to prevent the possibility of discomfort or social desirability bias introduced by the presence of the adolescents of the opposite sex, and to include concerns from both gender groups. The participants were one group of four female adolescents, one group of three male adolescents, one group of four mothers, and one group of two mothers and one father. All the adolescents were 13 years old; six (86%) adolescents identified as “White/European American,” while one (14%) indentified as “Other,” but did not specify. The mean duration since being fitted with brace was 1.3 years (SD = 1.04) and ranged from four months to three years. All the adolescents lived in the suburbs of a Midwestern city.

Procedures. Following IRB approval, the study was explained and the parents consented and the adolescents assented in parent/child dyads prior to the sessions. The

adolescents and their parents were asked to answer interview questions in their own words, in face-to-face group interviews. The parents and adolescents were interviewed in separate rooms after hours at an orthotic provider's office. In order to reduce the effects of social desirability, the technician did not participate and no physicians were present. An exploratory qualitative cross-sectional design was utilized.

Measures: Structured group interview. Participants were interviewed using open-ended and follow-up questions concerning factors in a variety of domains that may influence brace-wearing. Behavioral theory guided the development of interview questions to provide information across various stimulus domains. See Appendix A for the list of interview questions. Answers were recorded by assistants and on tape recorders. The data were analyzed, sorted, and compiled with variables gathered from past literature and expert opinions (i.e., brace technician and orthopedic surgeon) according to thematic content.

Scoliosis Research Society-22r Patient Questionnaire (SRS-22r; Asher et al., 2006). To assess the adolescents' health-related quality of life for descriptive and comparative purposes, the SRS-22r (Asher et al., 2006), which is a 22 item self-report designed for patients with idiopathic scoliosis, was used (see Appendix B). The SRS-22r provides ratings for five independent domains (functioning/activity, pain, self-image/appearance, mental health, and satisfaction with management). Though only relatively recently developed, the psychometric properties of the original SRS-22r have been well-studied. Internal consistency, test-retest reliability (Asher et al., 2006; Asher, Min Lai, Burton, & Manna, 2003b), concurrent validity (Asher, Min Lai, Burton, & Manna, 2003c; Glattes, Burton, Lai, Frasier, & Asher, 2007), and discriminant validity (Asher, Min Lai, Burton, & Manna, 2003a) have been demonstrated. For the revised version, which altered question 18 to

improve psychometrics, internal consistency ranged from .77 for self-image to .89 for satisfaction with management for adolescents in one study (Asher et al., 2006) and in another study, internal consistency ranged from .71 for self-image to .93 for satisfaction with management for adolescents (Glattes et al.). In addition, test-retest reliability ranged from .56 for satisfaction with management to .80 for pain for adolescents (Glattes et al.). Further, the SRS-22r has been shown to be responsive to changes in self-image, pain, and functioning following surgical intervention (Asher et al., 2003c).

Results

The adolescents' scores on the SRS-22r are shown in Table 3. When compared using one sample *t* tests, the adolescents' quality of life in the domains of functioning and self-image were worse than a comparator sample of adolescents with scoliosis (Glattes et al., 2007), but their pain and satisfaction with care were better and their mental health did not differ.

Table 3

Mean (Standard Deviation) Subscale Scores for the SRS-22R

	Domains				
	Function/ activity	Pain	Self-image	Mental health	Satisfaction with management
Mean (standard deviation)	3.6 (.25)	4.7 (.38)	3.6 (.43)	4.7 (.43)	4.7 (.27)
Glattes et al., 2007	4.5 (.65)	4.3 (.70)	4.1 (.63)	4.4 (.49)	4.0 (.82)
t test Sig.(2-tailed)	>.001	.03	.02	.41	>.001

Since our purpose was to assess the variety of factors that may contribute to adolescents' decisions to wear a brace, the frequency of the each response was not a focus of the analysis. In addition, the group format may have reduced the number of responses for

each type when an adolescent assumed another was speaking for them when their concerns were the same. Consistent with other studies, adolescents identified discomfort and various settings as making it difficult to wear a brace. However, they also identified feeling different as making it difficult, but supportive family and friends as making is easier to wear their brace.

Comfort and freedom of movement: Adolescent perspective. Responses that indicated the adolescents found it difficult to wear the brace because of comfort and freedom of movement, such as "I have to take it off to swim" and "can't jump on the trampoline like sisters," were identified on 12 questions (questions number 1, 2, 4, 7, 9, 10, 11, 12, 13, 20, 24, 37 of the 23 applicable questions). Sitting on stools and ducking for tornado drills at school, doing chores at home, riding in cars, and visiting places like amusement parks and sporting events were identified as difficult because of the brace. Adolescents stated that they would take off the brace to move around more easily and to swim, dance, play sports, and go to parties and sporting events. It should also be noted that some of the teens said that they were uncomfortable without the brace and they wore it to improve their backs as they get older and to avoid surgery.

Self-consciousness: Adolescent perspective. Responses that indicated adolescents do not like the brace to be seen by others, such as "I just don't like others knowing I wear it. It makes me feel different" and "I keep it hidden unless I am with friends who do not care" were identified on 16 questions (questions number 1, 2, 3, 4, 6, 10, 11, 12, 14, 19, 20, 21, 22, 23, 37, 38 of the 27 applicable questions). It was easier to wear the brace at home or close friends' houses because they were not treated differently ("its easier with friends who know about it, they understand more," friends "don't judge me," "don't ask questions," and

"use humor"), but at restaurants and at school they tried to keep it hidden. Although some adolescents were teased by peers ("kids can be mean 'bout that kind of stuff") and more rarely by friends ("they playfully poke and whack me in the backside because they know I have the brace," and "friends call me turtle"), it was also hard for them to be constantly asked about the brace by concerned strangers ("they keep asking about it"). They feared being defined by the brace and not as themselves ("people think about me differently; it's not my personality," and "I hope they do not think differently about me because of it"). Concerns about the opposite sex were referred to only once, by a female who said she did not like to wear the brace (around) "boys, especially the ones I like," but other adolescents in that group agreed.

Comfort and freedom of movement: Parent perspective. The parents' responses indicated that the adolescents found it difficult to wear the brace because of comfort and freedom of movement, such as "sometimes it's not conducive to activities" and "can't bend over; it's hard for her to get her socks and shoes on," as identified on 13 questions (questions number 1, 2, 3, 4, 5, 7, 9, 11, 13, 16, 18, 23, 24 of the 23 applicable questions). Gym class, heat and rashes, sitting for long periods in class, overnight trips away from home, using the bathroom, and places like amusement parks were identified as difficult because of the brace. They knew about and often allowed their child to take off the brace to move around more easily and to eat, swim, sing, dance, play sports, and go to parties and sporting events. Inconveniences related to brace-wearing were finding safe storage places, braces not fitting into gym lockers, needing to get help to put the braces on, and finding clothes that fit. Parents also said that their child was uncomfortable without the brace and

they wore it to improve their backs as they get older and to avoid surgery, which the parents frequently used as a motivator for brace-wearing.

Self-consciousness: Parent perspective. The parents also indicated that their children do not like the brace to be seen by others, but they put more emphasis on being embarrassed. Responses such as "he opted out of gym class because (he) doesn't know how to handle it…very embarrassed and self-conscious" and "she doesn't like to be different" were identified on 11 questions (questions number 1, 2, 3, 4, 6, 7, 10, 11, 13, 20, 21 of the 27 applicable questions). The responses varied greatly and ranged from their child being indifferent to wearing their brace to their child being "traumatized" about others finding out about the brace. Several of the parents suggested that a support group for the children and parents would help them deal with the practical and emotional difficulties since few of them encountered other families dealing with the challenges of wearing braces.

Discussion

The adolescents and parents identified comfort, freedom of movement, and feeling different and embarrassed as issues that made wearing a brace for AIS difficult. The adolescents often took off their brace to swim, dance, play sports, sing, and go to parties, amusement parks, and sporting events. Consistent with Behavior Analytic models, past difficulties with movement and performance were associated with anticipated difficulties, and the adolescents admittedly took off their brace prior to participating in activities and did not appear to reevaluate each time whether their brace posed a problem. Concepts from Behavior Analytic Theory that guide interpreting variables related to adolescent brace-wearing are negative reinforcement, establishing operations, matching law,

reinforcement/punishment schedules, generalization, and rule governed behavior, relational frame theory.

In the simplest of Behavior Analytic Theories, the adolescents' brace-wearing and non-brace-wearing behaviors appear to be positively reinforced, negatively reinforced, and positively punished. In the long-term, wearing the brace provides benefits to physical appearance and condition (positive reinforcement), and avoiding surgery (negative reinforcement), but in the short-term brace-wearing may be punished by physical and emotional discomfort. Conversely, not wearing the brace provided benefits by resulting in feeling accepted (positively reinforcement), avoiding physical and emotional discomfort (negative reinforcement), but may be punished by worsening physical appearance and condition and making surgery more likely. In the presence of conflicting consequences, more elaborate theoretical constructs could be instructive: establishing operations, matching law, schedules of reinforcement and resistance to extinction, and verbal behavior.

The presence of supportive persons and the demand for physical activity appeared to function as establishing operations for the behaviors of wearing and not wearing their brace, respectively. Establishing operations increase or decrease a behavior by increasing or decreasing the effectiveness of a reinforcer or punisher (Laraway et al., 2003). In the presence of family and friends, the value of wearing the brace appeared to be increased by increasing the effectiveness of feeling accepted. During the demand for physical activity, the value of not wearing the brace appears to be increased by increasing the influence of improved flexibility on physical performance. Matching law provides a framework to understand the adolescents' choice in the presence of competing establishing operations. The matching law describes that the ratio of two behaviors, B_1/B_2, is equal to the ratio of

reinforcement, R_1/R_2, and the relative rate of each reinforcer is dependent on the collective values, as a function of rate, duration, quality, delay, bias, and sensitivity for the delivery of reinforcement. The adolescents were most comfortable with family and close friends, because they felt understood and their condition was accepted. When around other peers, new acquaintances, and strangers, they feared being thought of or treated as different. Whether the adolescents thought of person as supportive was likely a function of the collective value their reinforcers, such as understanding and acceptance. The adolescents were able to wear their brace more often in the presence of supportive persons even while also in the presence of unsupportive persons. Likewise the higher the value of improved flexibility or physical performance, the less likely the adolescent was to wear the brace. For example, the adolescent may have been more likely to remove the brace for gymnastics and competitive swimming, but less likely to for walking and recreational swimming.

The observation that adolescents reported very little anxiety, yet at least one parent reported more anxiety for the adolescent, might be explained by schedules of reinforcement when anxiety is viewed as a response to situations. Continuous reinforcement ratios produce high rates of continuous rates of behavior, but fixed intervals schedules produce increasing rates of behavior as the reinforced or punished situation approaches and a quick reduction in rate after the situation is over. When adolescents are first prescribed a brace, they do not know how to predict when they will be embarrassed by others seeing the brace and predict a continuous ratio and they are initially highly anxious. As they learn to predict punishing, such as being asked unwanted questions or not being able to participate in activities or situations, adolescents have a more variable pattern of anxious behavior. During the group interview session, adolescents were less anxious because they were with others with similar

problems. However, their parents may have been reporting on more distal reactions. For this reason, it may be important to assess proximal mood reactions as a measure of the adolescents' evaluation of the reinforcer/punishers expected or experienced during the situation.

Generalization is when the consequences to specific stimuli or in one situation are thought to operate in different but similar stimuli or situations. Generalization is adaptive when similar negative consequence are avoided without direct experience, but maladaptive when the consequence are not the same. Adolescents may generalize decreased performance during one physical activity to similar situation without directly experiencing difficulties in the new situation. As a result, they may not be wearing their braces in situations where it would not pose a problem. To prevent others from finding out about the brace, the adolescents avoided wearing the brace to special social occasions, but being thought of as different if their brace is noticed may not have been a consequence. Another important problem is that even if the adolescent does not experience a negative consequence in one of the generalized situations, that unlearned contingency relationship is not likely to be generalized to other situations, but must be experienced in each situation, making extinction of not wearing a brace in anticipated problematic situations difficult.

Rule-governed behavior is one type of verbal behavior thought to be the source of some irrational beliefs and important in predicting adherence behaviors. Rule-governed behaviors are controlled by intra- or interpersonal verbal antecedents that function as discriminative stimuli to specify the contingencies of the behavior, especially if the associations were experienced in the past (Catania, 1995; Skinner, 1969). Some of the adolescents reported being tired of answering questions about their brace and their brace

being the focus of attention. The questions may have reinforced the belief that their brace was obvious and unusual and that they are different. However, the verbal behavior of reassurance and reminding of future positive consequences symbolize the positive reinforcement of acceptance and physical benefits and may moderate the actions of others when either thought of by the adolescent or provided by other individuals.

The symbolic reference patterns in Relational Frame theory may explain the negative connotation of being "different." One of the tasks of adolescence is to learn to socialize independently and this is done by trying to fit into social networks. When adolescents are perceived/labeled as different, they may not fit into a particular social network or may be socially awkward and not fit into any available network. The adolescents and especially the parents pointed out that they knew very few other adolescents with AIS. Having scoliosis when no other adolescent they know does, in essence, make the adolescents different. Having scoliosis and being different is associated with not fitting in with social networks where people do not have scoliosis. The brace is associated with having scoliosis and makes it more noticeable. When the brace is noticed, the relational frame associated with being different that threatens fitting in is activated.

Our findings can be explained by the Behavioral Analytic constructs of establishing operation, matching law, schedules of reinforcement, generalization, verbal behavior, and relational-frames. Establishing operations and matching law explain the differential value of supportive persons versus others and improved flexibility versus reduced performance. The fixed ratio schedules of reinforcement explain the proximal change in mood responses as difficult situations approach. Generalization explains the not wearing the brace during activities requiring similar flexibility and the need to experience success when wearing the

brace in each generalized situation before the behavior is changed. Verbal behavior explains how reassurances become associated with the reinforcement of acceptance and reminders are associated with the reinforcement of future physical benefits. Relational-frames explain the difference in association of the word "different" for adolescents than for other age groups and how the brace becomes associated with the frame, including the negatively associated consequences. Although proximal thoughts and moods may be indications of the presence and value of stimuli, global measures illuminate general tendencies, such as not following rules, but may not be accurate at predicting specific behaviors, such as brace-wearing.

The adolescents' and their parents' responses suggest that specific situations, such as particular places, unsupportive people, certain physical activities, anxiety about others' (negative) evaluation, and whether they believed the brace would not be beneficial may be predictors of not wearing their brace. The findings are consistent with two previous studies that found that comfort and social issues were related to adolescents wearing their brace for AIS. In one study, the most frequently endorsed problems were pain and skin chafing or rashes; many of the participants refrained from activities due to their brace and tried to keep others from knowing about their brace (Andersen et al., 2002). Similarly, in a second study, pain and difficulties when sleeping were frequently noted problems in adolescents with poor adherence (Korovessis et al., 2007).

Unlike the present investigation, both of the above-mentioned studies suggest that being with friends predicted non-adherence. However, they did not note what activities the adolescents were engaged in with their friends. The previous studies also indicated that the adolescents' reactions to peers, especially of the opposite sex (Andersen et al., 2002),

teachers, and family (Korovessis et al., 2007) affected brace wearing, but our findings suggest that adolescents are more likely to wear their brace in the presents of friends, family, and teachers.

This preliminary phase to the main investigation did illuminate that adolescents categorized and described factors slightly differently than the way they are referred to in literature or by adults. For example, the adolescents did not say they were embarrassed by their brace but that they tried to avoid feeling different. They also distinguished close friends and family as protective from other peers and other adults as making them uncomfortable. They also emphasized discomfort and inflexibility during activities as risk factors for not wearing their brace. In fact, many of the times they did not wear their brace seemed condoned by their parents.

The findings of this group interview suggest that investigation of brace-wearing should use behavioral constructs to assess the presence of friends, other peers, parents, family, and other adults. The investigations should also differentiate between activities requiring flexibility (e.g., sports) from more sedentary activities (e.g., watching TV); social activities (e.g., socializing) from more solitary activities (e.g., using a computer). Mood is a behavior associated with whether a person is experiencing or anticipating positive or negative consequences. Anxiety was indicated as associated with situations when adolescents had difficulties wearing their brace. It may also be helpful to assess the adolescents' mood during events, because their evaluation of the situation may be an important interpersonal factor. The DRM questionnaire in the primary investigation incorporate the adolescents' word choice and level of detail in subgroups of categories to reflect their finer distinctions (see the *Methods* section of the primary investigation).

Primary Investigation

Purpose

Prior investigations of the variables that influence adolescent brace-wearing are sparse and their findings are not consistent across studies. Most of the studies that have examined psychosocial factors relied on patients' retrospective self-reports and on chart reviews, which may be biased or inaccurate. In contrast, the more rigorous objective studies that have piloted methodologies and instrumentation have provided information about temporal relationships but have not investigated psychosocial influences. Furthermore, behavioral theories advocate the assessment of environmental, interpersonal, and intrapersonal variables proximal to the events. Well-suited for behavioral research are single-case designs that individually assess multiple events instead of relying on the participants to average ratings across several events. The purpose of this investigation was to assess, using a single-case design replicated across multiple participants, which psychosocial or situational variables reported within 24 hours predict objectively measured concurrent orthopedic brace-wearing for adolescents.

Hypothesis 1. Analysis of situational variables across individuals can be accomplished by having several adolescents report on several events over several days, thus making it possible to control statistically for individual tendencies. Published investigations (Andersen et al., 2002; Korovessis et al., 2007) and the preparatory investigation for the current study suggest that individual differences in situational variables (environmental and interpersonal), and their evaluation of the events (intrapersonal) may influence collective adolescent brace-wearing. It was hypothesized that adolescent brace-wearing *across* participants would be influenced by activities, social contacts, pain/discomfort, negative and

positive affect, interest, competence/self-efficacy, and fatigue at the time individually and in combination with other variables after controlling for individual features.

Hypothesis 2. Consistent with behavioral traditions, analyses of the individual participants provide both information about variables that may be significant for the individual patients and clinically useful information. Having individuals identify and report on several events over several days should provide enough data to analyze factors influencing brace-wearing for each individual. As the environmental, interpersonal, and intrapersonal variables were the same as those used in the group analysis, it was hypothesized that adolescent brace-wearing *within* individual participants would be influenced by activities, social contacts, pain/discomfort, negative and positive affect, interest, competence/self-efficacy, and fatigue at the time individually and in combination with other variables.

Hypothesis 3. Self-reported adherence has been consistently underreported when compared with objectively measured adherence in previous investigations (Morton et al., 2008; Nicholson et al., 2003; Takemitsu et al., 2004; Vandal et al., 1999). Therefore, environmental, inter- and intrapersonal variables associated with brace-wear may differ for objective and subjective reports of adherence. Likewise, it was hypothesized that participants would overreport brace-wearing when compared to objective measures of brace-wearing and that factors influencing reported brace-wearing would differ from factors influencing actual brace-wearing.

Hypothesis 4. Previous investigations have suggested that distal assessments of pain (Andersen et al., 2002; Korovessis et al., 2007), and expectations about treatment (Morton et al., 2008) were associated with brace-wearing. Therefore, it was hypothesized that

adherence would be associated with pain levels and expectation of treatment success, as well as functioning/activity levels, satisfaction with self-image/appearance, mental health, and satisfaction with the medical management of the scoliosis.

Method

Participants. Twelve adolescents were recruited by an orthopedic technician in the suburban region of a Midwestern city. Inclusion criteria were 12 to 17 years old; prescribed an orthopedic brace for at least three months; and diagnosed with idiopathic scoliosis. Participants were excluded if they or their parents did not understand written English or the participant was diagnosed with a significant co-morbid disease (e.g., Duchene's Muscular Dystrophy, spina bifida, cerebral palsy). No data were available for one participant who completed the first phase, but declined to continue, and for another participant who did not provide data for the second phase. The final group analysis was completed for nine participants. All the participants whose data were not used were female; one was African American and the other two were White.

Independent *t* test using SPSS for Windows 11.5 (SPSS Inc., 2002) indicated that the adolescents who did not continue or were dropped from final analysis did not differ from the adolescents included in the final analysis, in terms of the other demographic variables described in Table 4. Thus, there was no discernible pattern to attrition.

In the final analysis were seven females and two males, mean age 13.2 $\pm$ .97 years (range 12 - 15 years), mean grade in school was eighth (range sixth to tenth grade), and none received special education assistance. Seven adolescents identified as White/not-Latino, one as Middle Eastern, and one as Multiracial. All the parents were married, had two to three children in the home, and earned an average family annual income of $75,000 to $99,000.

All participants had medical insurance, and four required referrals. Two participants required emergency room visits; four, unplanned medical visits; six, scheduled medical visits; and all, spine-related medical visits in the last six months. The mean number of months participants wore a brace was 30.9 (range 2 – 67), and mean number of braces they have worn were 2.4 (SD = 1.1, range 1 – 4). Five participants had right thoracic/lumbar curves, one had a left thoracic/lumbar curve, one had a thoracic/lumbar curve of unreported direction, and two had right thoracic curves. The mean of the participants' initial curves or Cobb angle (their greatest recorded curve) was 27.5 degrees (*SD* = 4.9, range 21 – 36) and the mean of their current curves or Cobb angle (the greatest recorded curve for the participant) was 25.3 degrees (*SD* = 5.9, range 19 – 35). Eight participants did not have curves progress more than five degrees, but one participant's curve has increased by seven degrees. All the participants were clients of the same brace technician but were seen by four different physicians at the time of the study, and three had seen a different physician in the past.

Table 4
Frequency of Demographic Variables in Sample for Final Analysis

		Participant	
		Frequency	Percent
Gender	Male	2	22.2
	Female	7	77.8
Child ethnicity	White	7	77.8
	Middle Eastern	1	11.1
	Multicultural (Latino/white)	1	11.1
Now married	No	0	0
	Yes	9	100
Number children living in house	2	4	50.0
	3	4	50.0
Number adults living in house	1	1	12.5
	2	7	87.5
	4	1	12.5
Child been diagnosed with a behavioral/psych condition	No	6	75.0
	Yes	2	25.0
Child has other CMCs requiring medical attention	No	6	75.0
	Yes	2	25.0
Other child been diagnosed with a behavioral/psych condition	No	4	50.0
	Yes	4	50.0
Child has other CMCs requiring medical attention	No	8	100
	Yes	0	0
Health insurance	No	0	0
	Yes	9	100.0
Need referrals	No	4	50.0
	Yes	4	50.0
Caregiver parent education	Some college credits	5	62.5
	2 yr degree	1	12.5
	Completed graduate/professional school	2	25.0

Table 4 (continued)
Frequency of Demographic Variables in Sample for Final Analysis

		Participant	
		Frequency	Percent
Other parent education	High school	1	12.5
	Some college credits	5	25.0
	2 yr degree	1	12.5
	Completed graduate/professional school	4	50.0
Primary caregiver employment	full-time	2	25.0
	part-time	3	37.5
	self-employed	1	12.5
	Homemaker	4	50.0
Others parent employment	full-time	7	87.5
	Part-time	1	12.5
	Self-employed	1	12.5
Household income	< $10,000	1	12.5
	$25,000 - $49,000	1	12.5
	$50,000 - $74,000	1	12.5
	$75,000 - $99,000	3	37.5
	> $100,000	3	37.5
Public school		8	87.5
Extra assistance/special ed		0	0
Days of school child missed in past 6 months	None	6	75.0
	1-5	2	25.0
Spine-related scheduled visits	1-3	4	50.0
	4-8	4	50.0
Other scheduled medical visits	0	2	25.0
	1-3	6	75.0
Unplanned medical appointments for other problems	0	4	50.0
	1-3	4	50.0
ER visits for any problem	0	6	75.0
	1-3	2	25.0
Can child participate in recreational outdoor activities	Yes, easily	8	100.0
Can child participate in unorganized sports	Yes, easily	8	100.0
Can child participate in competitive sports	Yes, easily	8	100.0

Baseline Measures

Background. The Background Questionnaire was modified from a previously-used questionnaire designed to gather data for a larger cross-sectional study of adolescents with AIS (Hoodin et al., 2007, November). It included standard demographic information (e.g., age, education, occupation of caregiver), medically relevant behavioral and environmental information (e.g., income sources including government assistance, financial impact on household of child-patient's medical problems), and social information (e.g., number of people residing in household, availability of social support). In this study, the demographic variables provided a detailed description (e.g., age, gender, degree of curve, time since fitted with brace) of the adolescents in this investigation (see Appendix C).

Quality of life. The Scoliosis Research Society-22r Patient Questionnaire (SRS-22r; Asher, Lai, Burton, & Manna, 2003a) was used to further describe this sample of adolescents' functioning. This instrument and its psychometrics are described in the Methods section of the Preparatory Investigation (page 59 of this document).

Treatment expectations. The Expectations Subscale of the Pediatric Outcomes Data Collection Questionnaire of the American Academy of Orthopedic Surgeons (PODMS Subscale: Expectations for Treatment; Bridwell et al., 2000) was used to assess the patient's expectations with regard to treatment outcome. The psychometric properties of this subscale used in isolation have not been studied. Therefore, its use in this study may be considered experimental. Nine questions were asked ("As a result of your treatment, do you expect them to have pain relief, look better, feel better about self, sleep more comfortably, do more activities at home, do more activities at school, do more recreational activities, do more

sports, and be free from pain and disability as an adult?"). Response options were on a 5-point Likert scale of agreement/disagreement with each question (see Appendix C)

Repeated Measures

Events. The Daily Reconstruction Method instrument (DRM; see Footnote 1; Kahneman et al., 2004) was modified to be age-appropriate for adolescents and delivered on a handheld computer (see Appendix D). The *Episodes Questionnaire* prompted the participant to use a separate packet of paper forms to list and enumerate events of the past 24 hours. Next, the participants reported the beginning and ending time of each event, and situational factors associated with each event: activities, location, social interactions, and pain or discomfort. In order to tap the influence of activities, the participants answered "What were you doing?" by checking all the activities on a list that applied at the time (e.g., *commuting, studying, working, shopping, doing housework, eating, socializing, swimming, praying/worshipping/meditating, dancing, watching TV, nap/resting, showering/hygiene, using computer/internet/email, talking on the phone, engaging in intimate relations, exercising, playing organized sports, playing informal unorganized sport, playing board games, praying/worshipping, special occasion/award ceremony,* and *other*). To tap the influence of the location, the participant answered, "Where were you?" and checked whether they were *home*, *someone else's home*, *school*, *shopping, outdoors, work,* or *somewhere else*. In order to tap the influence of social contacts, the participants first answered the question "Who were you interacting with?" and then "Who was else was present?" by checking all the responses that applied (i.e., *friends, parents/relatives, brothers/sisters, boyfriend/girlfriend/partner, other classmates/peers,* and *other adults*).

To assess self-reported adherence, the participant responded to "Were you wearing your brace?" by checking *all of the time, part of the time,* or *not at all*. If the participant indicated that he or she was not wearing his or her brace for any part of the event, the participant was asked to answer, "Why did you remove your brace?" by checking all the responses that applied (i.e., *uncomfortable, trouble bending/move/twist, do not have to, clothing did not look or fit right, trouble putting on, do not want others to know, other reason*). If they did not want others to know, they were asked "Why did you not want others to know you were wearing a brace?" and asked to check all the responses that applied (i.e., *embarrassed, did not want to explain, did not want others to think of me differently*). In order to tap the level of pain or discomfort, participants responded to "How comfortable was your brace/back at the time" by using a 7-point Likert scale with 0 being *comfortable* and 6 being *extremely uncomfortable.* If it was extremely, very, or somewhat uncomfortable, they were asked, "What made your brace uncomfortable?" and checked all the responses that applied (i.e., *too hot, skin problems, spine/rib/muscle pain, poking, rubbing*).

As the measure of subjective adherence, the adolescents entered the answer "How many hours did you wear your brace during the last 24 hours?" Variables identified by the targeted adolescents were added to existing variables obtained through surveys of the literature and experts.

General Questionnaire. In order to acclimate the participant to checking and using a handheld computer to report on the behaviors and moods, another modified version of the DRM was constructed that included the same questions as above. However, the questions asked the participant to report only once on the entire day. For example, when they were

asked, “Who were you interacting with?” they checked everyone they interacted with in the previous 24 hours.

Mood. This study employed the mood scales used in previous DRM studies (Kahneman et al., 2004) with nine adjectives modified from the positive and negative affect scales developed by Deiner and Larsen (1984). Consistent with the previous DRM studies, the participants were prompted to respond to the question, “How did you feel during this episode?” by rating adjectives that assess positive (*happy, warm/friendly, enjoying myself*) and negative (*frustrated/annoyed, hassled/pushed around, depressed/blue, angry/hostile, worried/anxious, criticized/put down,*) mood valences using a 7-point Likert scale with 0 being *not at all* and 6 being *very much.* Three additional items that tap self-efficacy (*competent/capable*), general arousal and fatigue (*tired*), and interest in or control over the event (*impatient for it to end*) were also assessed. Although psychometrics are not available for the subscales used in the previous DRM studies, similar adjective checklists show adequate independence, reliability, and stability when assessed generally or averaged over weeks or months and adequate independence, reliability and necessary variability when assessed momentarily (Diener & Larsen, 1984; Diener, Larsen, Levine, & Emmons, 1985; Watson, Clark, & Tellegen, 1988).

The decision to modify the original DRM for this study took several issues into consideration. First, affect scales validated for adolescents (Huebner & Dew, 1995; Terry, Lane, Lane, & Keohane, 1999) involve rating 20 to 24 adjectives. However, using them in this study would have been problematic on two counts: first, they would be too burdensome for rating several events during an individual day reconstruction; second, reducing the scale length would invalidate the current psychometrics. Second, Russell and Ridgeway (1983)

validated opposing two-dimension affect scales (e.g., a continuum between happy and unhappy), but positive and negative affect scales have demonstrated poor correlation and to operate differently (Watson, Weber, Assenheimer, & Clark, 1995). Third, Stone has frequently used modifications of the positive and negative affect scales developed by Deiner and Larsen (1984) in EMA studies (le Grange, Gorin, Dymek, & Stone, 2002; Marco et al., 1999; Smyth, Soefer, Hurewitz, Kliment, & Stone, 1999).

Electronic temperature and pressure monitors. The Hobo H08 data loggers (Onset Computer Corp., MA; http://www.microdaq.com/occ/h8/4channelx.php) were used to sample in ten-minute intervals brace pressure at two apex points and the temperature of the inside lining and the outside surface of the brace. The loggers were fitted unobtrusively to the external portion of the brace. Each logger measures 2.4 x 1.9 x 0.8 inches (60 x 48 x 19 mm), weighs approximately one ounce (27 grams), and is capable of collecting over 32,000 measurements, far exceeding the anticipated 8064 measurements generated by participants using a 10-minute sampling rate to collect information from two temperature and two pressure sensors for 14 days. Communication with the logger was accomplished using BoxPro 4.3 Software (Onset Computer Corporation, 2002) and provided cables. The technical information provided by Onset reports that the loggers operate reliably in temperatures between -4°F to +158°F (-20°C to +70°C) and in relative humidity between 0 to 95%, and are accurate to ±1 minute per week at +68°F (+20°C). The temperature sensors that were inserted in the lining and outside the brace can measure temperatures between -40° to 212°F (-40° to 100°C), are accurate to ±0.9° at 68°F (±0.5° at 20°C), and respond within one to three minutes. The probes have a stainless-steel sensor tip that measures 0.20" x 1.0 inches (0.5 cm x 2.5 cm) and weighs 1.3 oz (37g). The pressure probes used 0.5 Inch Force

Sensing Resistor (FSR; Trossen Robotics) adjusted with a 1k Ohm standard resistor and connected to voltage circuits of the logger. The electronic monitor provided temperature and pressure ratings every 10 minutes to assess whether the participant was currently wearing his or her brace and whether enough pressure was being applied to the apex points of the brace to be effective.

Procedures

In-clinic session one. Following IRB approval, and after agreeing to participate, the parent signed the informed consent documents and HIPAA forms and the child signed assent. Because adolescent participants would likely be concerned about the confidentiality of the data and the findings, they were assured that results would not be disseminated to their physicians or parents until de-identified and aggregated. In the required assent and parental consent forms, the confidentiality and dissemination of the findings was fully described (HHS; 2003). Then the participant's parent completed the Background Questionnaire, and the participant completed a quality of life questionnaire, treatment expectancy questionnaires, and the first entry of the General Questionnaire on the handheld computer.

At home for next 14 days. The participants answered the same questions they completed in the clinic on the handheld computer at a convenient time during the evening on six randomly selected evenings out of the next 14 days, as prompted by the handheld computer.

In-clinic session two. The participant was taught how to complete the modified DRM (Kahneman et al., 2004). In order to ensure that participants understood the DRM and handheld computer procedures, each participant self-reported on events that occurred during

the previous day while a researcher was available to assist with questions or problems. In addition, their brace was fitted with an electronic monitor during this session. The monitor was activated and fitted with the assistance of an orthotic technician. In ten-minute intervals, the monitor unobtrusively sampled the pressure at two apex points and the temperature of the inside lining and the outside surface of the brace.

At home. At home, the handheld computer prompted the participant to complete the assessment on the selected evening and automatically time-stamped the entry to allow evaluation of timely completion. On a worksheet provided by the investigator, the participant reconstructed a time-ordered list of events that occurred during the evening and nighttime of the previous day, and morning and afternoon of the current day. Then the participant answered the questions on a handheld computer for each event they listed on the worksheet. Information elicited included the beginning and ending time of the event, what activity they were participating in, where they were, with whom were they interacting, who else was present, whether they were wearing their brace (if they were not, when and why they removed it), how comfortable their brace was at the time, and their affect, interest, competence/self-esteem, and fatigue at the time. The participant completed the quality of life and treatment expectancy questionnaires prior to the follow-up visit.

Final session in clinic. After the participant completed six the DRM assessments, the monitor was removed at the clinic, the data were downloaded, and questionnaires and handheld computers collected.

Data Analysis

Collecting data for several events over six days provided a panel data set that was analyzed to identify significant causal effects across participants and for each participant.

Although the participants provided data over six days, change due to time was not expected and was controlled for as part of the unobserved heterogeneity. For within-case analyses, 50 data points are considered minimum and 100 are considered optimum to provide the adequate power and stability for analysis (Kazdin, 2003). When examined over eight participants who provided a mean of 65 data points (range 47 – 81) each, 567 data points were available, thus providing adequate power for across participant designs.

Dependent variables: Brace-wearing. In order to test the hypotheses about the causal effects of brace-wearing, the dependent variable was whether the brace was worn during each event. Although both temperature and pressure on the brace were measured to determine if the adolescent had the brace on, the pressure measurements provided more variable readings and although it could determine whether the brace was worn, it did not add any information to what was gathered by the temperature readings. However, for one participant, the temperature readings were erroneous and the pressure readings were substituted to determine brace-wearing. The temperature readings thus provided adequate readings to determine wearing patterns for the events.

First, the logger data for the temperature every ten minutes were aligned with each event associated with the same time period. To create a binary measure of adherence, each temperature reading from between the brace and the lining over 80 degrees and greater than the temperature outside the brace was coded as the brace “being worn.” Temperature readings less than 80 degrees or the same as the temperature outside the brace were coded as the brace “not being worn.” Readings with temperatures over 120 degrees or under 49 degrees were not used.

Then the collective readings for each event were coded as “being worn” if all readings were “being worn” and as “not being worn” if all readings were “not being worn.” In order to provide binary variables, events during which they put their brace on were conceptualized to be similar to situations in which they would wear their brace and events during which they took their brace off were conceptualized to be similar to situations in which they would not wear their brace. Therefore, readings that indicated the participant was at first not wearing their brace then put it on (i.e., “not being worn” readings, then “being worn” readings) during the event were coded as “being worn.” Readings that indicated the participant was first wearing their brace but then took off the brace (i.e., “being worn” readings then “not being worn” readings) even if they put it back on (i.e., “being worn” readings, then “not being worn” readings, then “being worn”) during the event were coded as “not being worn.” Similarly, the participants’ self-report of whether they wore their brace during the event was coded as “being worn” or “not being worn.” In summary, the algorithm described above for the recoding “put on the brace” to “worn” and “take off brace” and “both” to “not worn” was used to make a binary variable, but the theoretical approach balances the error that may be introduced by collapsing categories.

The various measures of brace-wear are defined as follows:

Objective brace-wear. The objective brace-wear measures were of the percentage of time-sampled reading provided by the electronic monitors indicated the participant was wearing his/her brace compared to the total time sampled.

Objective brace-wear by event. The objective brace-wear by event was whether the time-sampled readings during the events indicated that the participants were wearing their brace or not.

Subjective brace-wear by event. The subjective brace-wear by event was determined from the participants' report of whether they wore the brace during the event.

Subjective daily report. Subjective daily adherence rate was the *mean* of the participants' responses to "How many hours did you wear your brace in the last 24 hours?"

Distal subjective report. The subjective distal adherence rate was interpreted from the participant's report once at the beginning of the study to "How many hours each day are you wearing the brace?"

Not brace-wearing. Even though logistical regression analysis provided goodness-of-fit, the odds-ratio has been posited to be more useful in reporting medical and clinical results than simply reporting variance and significance (Rutledge & Loh, 2004). Thus, in order to provide odd-ratios for not brace-wearing, mirror variables of non-adherence were created using the objective and subjective brace-wear during event.

Logistic regression. Since logistic regressions can also be limited by too few cases in variable cells (Mertler & Vannatta, 2002). Variables were combined if conceptually similar variables exist (e.g., parent, relatives, siblings), or deleted if unique (e.g., boyfriend/girlfriend). Participation in various activities were combined, based on the reasoning that some activities are similar in demands on the individual but differ in terms of individual preference or availability. Therefore, *swimming*, *dancing*, *exercising*, and *participating in organized* and *unorganized sports* were combined into *sports/exercise*. *Working* and *doing chores* were combined into *work/chores. Watching TV*, *napping* or *resting*, *using the computer*, and *playing board games* were combined into *passive/activity*. The mood variables were combined into subscales as described in the Measures section.

Similarly, if multicollinearity existed, the variables were collapsed or one deleted. Because *being with friends, peers other than friends,* and *adults other than relatives* are very different in quality when at school than when not at school, and intercorrelation between the variables may veil unique contributions of the variables, the variables were divided into *friends at school, friends not at school, peers at school, peers not at school, adults at school,* and *adults not at school*. Binary variables representing *friends at school* and *friends not at school, other peers at school* and *peers not at school,* and *other adults at school* and *other adults not at school* were created. Being at home was highly correlated with parents and siblings in early models and thus dropped from the model. However, *peers at school* remained highly correlated with *being at school* and with *other activities,* and thus *peers* were dropped. Some variables were not endorsed or endorsed rarely by the participants and were dropped prior to analysis. For this reason, *intimate relations,* and *being with a boyfriend or girlfriend,* were not used in the current analyses.

Analyses of the causal contribution of independent variables across the group and within individuals for the binary dependent measures of objective and subjective brace-wear and not wearing were accomplished using LOGIT with Intercooled Stata 9.0 software (StataCorp LP, 2006). Logistic regression requires no assumptions that the independent variables are normally distributed, linearly related, have equal variance, or have a linear relation with the dependent variable (Mertler & Vannatta, 2002). Unobserved heterogeneity within individuals was adjusted for using fixed effects estimators by creating dummy variables for each participant, removing unique variance in the across-participant analyses, and using a robust standard error clustering for the individuals. This method also removed variance attributed to gender, age, time since prescribed brace, social status, family

dynamics, and other fixed factors that may have differed by individual and influenced brace-wearing. As the most important overall research questions is what variables actually influenced participants to not wear their brace, the participant with the highest adherence rate was used as the comparator or indicator variable for the interaction effects of participant by causal effects. In conclusion, using the binary logistic regression that controls for many of observable and unobservable limitations in the data provided a robust analysis of the causal effects and the accuracy of self-reports of daily brace-wearing for individual adolescents and for the entire sample.

Results

Group Analyses of Objective Brace-wear

Hypothesis one. It was hypothesized that adolescent brace-wearing *across* participants would be influenced by activities, social contacts, pain/discomfort, negative and positive affect, interest, competence/self-efficacy, and/or fatigue at the time individually and in combination with other variables after controlling for individual features. Several individual variables were influential to the adolescents' brace-wearing, thus indicating the hypothesis was supported.

The overall objective brace-wear rate (worn/total time) for the nine participants in the final group analysis was 75.9% (range 59.1% to 91.0%) of the time measured by the monitor in ten-minute intervals. The participants wore their brace during 65.2% (range 28.3% to 91.5%) of events ("objective brace-wear by event"). The difference between these two rates was due to difference in the unit of measurement. The objective brace-wear rate is a measure of the percentage of *time* sampled readings provided by the electronic monitors over the entire period that indicated that participants were wearing their brace, whereas

"objective brace-wear by event" is an indicator of *frequency* of situations or events that they were wearing their brace and not a measure of actual time. Objective brace-wear by event with 'worn' coded as 1 and 'not worn' coded as 0, was used as the dependent variable influencing environmental, interpersonal, and intrapersonal variables. In order to provide an odds ratio for not wearing the brace, a second analysis was done with 'not worn' coded as 1 and 'worn' coded as 0.

As mentioned in the data analysis section, binary Logit analysis was used, controlling for heterogeneity by entering into the model independent dummy variables for each participant and using robust standard errors. No variables were dropped by the model, since the problematic variables were handled as described in the data analysis section. When using the Logit, a -251.25 log-likelihood goodness of fit (Prob > LR = <.001) for 567 observations was obtained (see Table 5). The model predicts 65% objective brace-wear by event as compared to the actual rate brace-wear by event which was found to be 63.4%.

Objective brace-wearing was strongly influenced by 'feeling competent in the situation' (OR = 1.49, 95% CI = 1.15 – 1.93, p =.04), and moderately influenced by 'studying at school' (OR = 7.25, 95% CI = 1.43 – 36.52, p =.016). Not wearing the brace as objectively measured was strongly influenced by being involved in *physical activities* (OR = 4.01, 95% CI = 1.90 – 8.84, p =.016) and by being with *adults when not at school* (OR = 2.6, 95% CI = .1.41 – 4.81, p =.002); moderately influenced by *hygiene activities* (OR = 2.95, 95% CI = .91 – 9.57, p =.07), and weakly influenced by *parents being present* (OR = 1.98, 95% CI = .81 – 4.85, p =.13), and *negative mood* (OR = 1.11, 95% CI = .99 – 1.25, p =.07). Hypothesis one was therefore supported by the identification of environmental variables (i.e., *being at school, physical activities, hygiene activities, studying when not in*

school), interpersonal variables (i.e., *presence of friends at school, other adults when not at school, and parents*), and intrapersonal variables (i.e., *feeling competent, and negative mood*) that differentially influenced actual brace-wearing.

Table 5
Logistic Analysis of Causal Effects of Objective Brace-wearing and Not Brace-wearing

	Brace worn = 1		Brace not worn = 1	
	Odds Ratio	95% CI	Odds Ratio	95% CI
Environmental				
Physical activity	.24***	.11 – .57	4.10***	1.90 – 8.84
Study at school	7.25**	1.44 – 36.52	.14**	.03 – .69
Studying not in school	.55	.18 – 1.67	1.81	.60 – 5.45
Riding in car/bus	.59	.24 – 1.47	1.70	.68 – 4.23
Socializing	1.20	.75 – 1.92	.83	.52 – 1.33
Talking on phone	1.01	.39 – 2.61	1.00	.38 – 2.56
Eating	.75	.35 – 1.63	1.33	.61 – 2.89
Hygiene	.34**	.10 – 1.10	2.95**	.91 – 9.57
Praying/worshipping	1.31	.17 – 12.48	.76	.08 – 7.28
Passive activity	.86	.52 – 11.43	1.16	.70 – 1.91
Work/chores	1.00	.24 – 4.21	.99	.24 – 4.16
Other activities	1.11	.71 – 1.75	.90	.57 – 1.41
Interpersonal				
Parents	.51*	.21 – 1.24	1.98*	.81 – 4.85
Brother/sister	1.02	.62 – 1.67	.98	.60 – 1.61
Friends at school	1.27	.52 – 3.07	.46	.11 – 1.92
Friends not at school	1.45	.68 – 3.09	.69	.32 – 1.47
Peers not at school	1.54	.54 – 4.41	.65	.23 – 1.84
Adults at school	1.94	.24 – 15.65	.51	.06 – 4.11
Adults not at school	.38***	.21 – .71	2.61***	1.14 – 4.81
Intrapersonal				
Comfortable	.1.19	.75 – 1.88	.84	.53 – 1.33
Positive mood	.94	.77 – 1.42	1.06	.87 – 1.29
Negative mood	.90*	.80 – 1.01	1.11*	.99 – 1.25
Competence	1.49***	1.15 – 1.93	.67***	.52 - .87
Tired	.91	.68 – 1.22	1.09	.81 – 1.46
Impatient	.98	.77 – 1.24	1.02	.81 – 1.28

*p=.1, ** p = .05, *** p < .01
Note: odds ratios for individual participant dummy variables increased the odds of not wearing their brace and were not reported

Post Hoc Interaction of Individual Participants

To investigate whether individual adolescents were less likely to wear their braces than the person with the highest brace-wear by event associated with the environmental interpersonal and intrapersonal variables from the previous analysis, logistic regression was used to interact each variable for which there was significant evidence with each participant dummy variable. These interaction analyses revealed very few variables that influence objective brace-wearing. Most participants were less likely to wear their brace when they felt more *competent,* four during *hygiene activities,* one when *studying when not at school*, one while participating in *physical activity*, and another while *studying at school* than the adolescent who wore their brace the most. It should be noted that for some participants, *hygiene, physical activity, parents, adults other than relatives, competent,* and *negative mood* too strongly predicted not wearing their brace and were dropped from the model. Wearing their brace was too highly correlated for some participants with *hygiene,* and *studying at school.* This means, for these individuals, these situations provided almost no variability, and so perfectly and invariably were associated with brace-wearing. Dropping these observations left 396 observations of the original 503.

Within Participant Analyses of Objective Brace-wear

Hypothesis two. As the variables used in the within-participant analysis of objectively measured brace-wear are the same as in the group analysis, it was hypothesized that adolescent brace-wearing *within* individual participants would be influenced by activities, social contacts, pain/discomfort, negative and positive affect, interest, competence/self-efficacy, and fatigue at the time individually and in combination with other variables. Hypothesis two was supported by identifying a few variables that are uniquely

predictive for some individuals and correlational analysis discovered several more variables that were associated with brace-wear for individual participants.

A Logit regression was performed using the same model as the group analysis to determine which variables influence whether the individual participants were actually (objectively) wearing their brace during events. Because the procedures were done independently on each of the nine participants, procedures for removing individual differences were not necessary. The mean number of observations per participant was 65 (range 47 – 81).

The results are reported in Table 6, but for five participants, there was no evidence that any of the variables influenced the dependent variable to a statistically significant degree, and only significant results were reported. For three participants, *physical activity* influenced not wearing their brace. For two participants, being with *adults other than their parents* and *eating* influenced not wearing their brace. For one participant *impatient* influenced not wearing his/her brace. For one participant, *being with hygiene, friends at school,* and *friends not at school,* for another *brother/sister* and *other activities* influenced wearing his/her brace, and for another *passive activities.* Similar to the group analysis, *physical activity* was the most frequent reason for not wearing their brace along with being with *adults other than parent when not in school,* but *mood, parents,* and *hygiene* were not. Furthermore, for one participant, being with *friends at school* and *friends not at school* was influential, but *studying at school* was not for any of the participants.

Table 6

Odds Ratio (Confidence Interval) for Significant Individual Logit Regressions (worn = 1)

	Participants			
	5 (n=58)	6 (n=78)	7 (n=81)	10 (n=77)
Environmental				
Physical activity		.04** (.003 - .59)	.003** (.00 - .04)**	1.05e-08*** (7.43e-10 – 1.49e-07)
Study at school				
Studying not in school				
Riding in car/bus				
Socializing				
Shopping				
Talking on phone				
Eating	.02*** (.001 - .40)			.11* (.01 – 1.38)
Hygiene	344.67** (.1.04 – 114075.1)			
Praying/worshipping				
Passive activity			.14* (.01 – 1.35)	
Work/chores				
Other activities				4.90e-15*** (1.09e-16 – 2.20e-13)
Interpersonal				
Parents				
Brother/sister				28.11** (1.14 – 694.08)
Friends at school	144.97** (1.13 – 18567.21)			
Friends not at school	21.41* (.78 – 585.38)			
Peers at school				
Peers not at school				
Adults at school				
Adults not at school	.004* (.00 – 1.62)			.06* (.002 – 2.67)
Intrapersonal				
Comfortable				
Positive mood				
Negative mood				
Competence				
Tired				
Impatient				.01* (.00 – 2.33)

*p=.1, ** p = .05, *** p < .01. Note: participants without evidence of significant influences were not reported (participants 1, 2, 3, 4, 8, & 9)

Logit regression within participants becomes problematic when correlations are high. In all but one of the individual regressions, 'study at school' was removed from the models because of high correlations with brace-wearing or collinearity with another variable. In fact, many variables were removed from the models for being strongly predictive with little variability. Since it is conceivable that individual participants may consistently wear their brace in some situations or not wear their brace in others, a simple correlational analysis was performed (see Table 7). Similar to the group analysis, for seven of the nine participants, *physical activity* was associated with not wearing their brace. For three participants, *parents*, *'adults not at school,* and being *tire'* were associated with not wearing their brace. For two participants, *riding in car/bus* was predictive of not wearing their brace. For at least one, *shopping, hygiene, eating, siblings, friends not at school,* and *negative mood* were predictive of not wearing their brace. Likewise, for four participants, *study at school* was associated with wearing their brace. For three participants, *friends at school* was associated with wearing their brace. For one participant, *talking on the phone* and *positive mood* were predictive of wearing his/her brace. *Studying not at school*, *passive activity, adults at school*, and *comfortable* produced mixed results.

Table 7

Frequency of Significant Correlations for Individual and & Total Participants.

	Participants									Total	
	1	2	3	4	5	6	7	9	10	Pos	Neg
Environmental											
Physical activity	-.24	-.31	-.56	-.42		-.37		-.36	-.24	0	7
Study at school		.77		.43	.27	.29				4	0
Studying not in school	-.24								.31	1	1
Riding in car/bus			-.26	-.31						0	2
Socializing										0	0
Shopping			-.39							0	1
Talking on phone							.25			1	0
Eating					-.30					0	1
Hygiene			-.36							0	1
Praying/ worshipping										0	0
Passive activity		-.35								1	1
Work/chores										0	0
Other activities										0	0
Interpersonal											
Parents	-.32	-.45							-.22	0	3
Brother/sister		-.38								0	1
Friends at school	.42			.34					.41	3	0
Friends not at school			-.41							0	1
Adults at school	.43	.77	-.29						.24	3	1
Adults not at school		-.30		-.39					-.34	0	3
Intrapersonal											
Comfortable		-.75						.48		1	1
Positive mood							.28			1	0
Negative mood									-.26	0	1
Competence										0	0
Tired							-.34	-.34	-.33	0	3
Impatient											

$p < .05$

Group Analyses of Subjective Brace-wear

Hypothesis three. It was hypothesized that participants would overreport brace-wearing when compared to objective measures of brace-wearing and that factors influencing subjectively reported brace-wearing would differ from factors affecting actual brace-wearing. Hypothesis three was partially supported by the participants overreporting on some measures of subjective measures of brace-wearing and by a slightly different pattern of associated variables as compared to objective measures.

A comparison of the objectively measured actual adherence rate and brace-wear by event with the subjectively measured adherence rate and brace-wear by event suggests the participants consistently overreported adherence compared to the objective measures. The association of the overall objective brace-wear by events with subjective brace-wear by event was $r_{(567)} = .61$ suggesting a moderately strong but imperfect relationship. The participants reported an average distal subjective adherence rate of 20.2 hours a day (range 17 to 23) or 84.4%. The participants reported an average subjective daily brace-wear rate of 80.2% (range 62.9% - 94.2%) hours per day and that they wore their brace during 69.6% (range 30.2% - 95.7%) of the events (see Table 8). Consistent with hypothesis three, the participants over-reported daily brace-wear by 4.3% (range -1.08% to 11.1%) and overreported brace-wear during event by 4.6% (range -5.3% to 13.6%). A one-sample *t* test showed that the difference between the participants' distal subjective report of adherence was significantly higher than the objective adherence rate ($t_{(7)} = 2.98$, $p = .02$). However, as indicated by a one-sample *t* test, objective brace-wear rates and more proximal subjective reports of brace-wear and brace-wear by event did not differ to a statistically significant degree ($p > .05$).

Table 8

Mean Percent (Hours per Day) and Objective and Subjective Brace-wear for Adherence Rate (Time in Brace) and Events

	% Distal	% Objective	% Subjective	% Objective	% Subjective

	subjective report	wear	daily report	event wear	event wear
1	N/A	77.3 (18.5)	83.8 (20.1)	71.6	85.2
2	70.8 (17)	59.4 (14.2)	62.9 (15.1)	28.3	30.2
3	89.6 (21.5)	89.0 (21.4)	87.9 (21.1)	89.2	83.9
4	83.33 (20)	78.9 (18.9)	84.6 (20.3)	67.2	75.9
5	77.1 (18.5)	62.3 (14.9)	65.8 (15.8)	43.8	43.8
6	83.33 (20)	64.6 (15.5)	73.3 (17.6)	45.5	55.8
7	91.67 (22)	81.0 (19.4)	92.1 (22.1)	80.0	77.3
8	100 (24)*	18.7 (4.5)*	‡	‡	‡
9	95.8 (23)	91.0 (21.8)	94.2 (22.6)	91.5	95.7
10	83.3 (20)	79.7 (19.1)	77.9 (18.7)	70.1	79.2
Mean	84.4 (20.2)	75.9 (18.2)	80.2 (19.2)	65.2	69.6

‡ participant did not provide enough complete events and was dropped from analyses
*not used in mean analyses

When the adolescents' self-report of wearing the brace during the events was analyzed in the same manner as the group analyses for hypothesis one, a slightly different pattern was indicated and a -196.34 log-likelihood goodness of fit (Prob > LR = <.001) for 566 observations was obtained (see Table 9). The model predicts 70% subjective brace-wear by event as compared to the actual rate of brace-wear by event, which was found to be 68.7%.

Brace-wearing was strongly influenced by *studying at school* (OR = 22.67, 95% CI = 2.35 – 218.65, p = .007), moderately influenced by *praying or worshipping* (OR = 3.57, 95% CI = 1.28 – 10.00, p =.015), being with *friends while at school* (OR = 7.45, 95% CI = 2.09 – 28.60, p = .04), *passive activities* (OR = 2.00, 95% CI = 1.01 – 3.99, p =.05), and weakly by being *comfortable* (OR = 1.78, 95% CI = .93 – 3.40, p =.08).

In order to provide odds ratios for not wearing their brace, another regression was conducted with "not worn" coded as 1. Not wearing the brace was strongly influenced by *physical activity* (OR = 5.58, 95% CI = 2.42 – 14.19, p < .001), *hygiene activities* (OR = 18.39, 95% CI = 4.13 – 81.87, p < .001), and being with *adults other than parents when not at school* (OR = 3.13, 95% CI = 1.45 – 6.75, p < .004).

Similar to the analysis of actual adherence for the group, environmental variables (i.e., being at *school, physical activities, hygiene activities, studying when not in school*), interpersonal variables (i.e., presence of *friends at school, other adults when not at school,* and *parents*), and intrapersonal variables (i.e., *feeling competent,* and *positive* and *negative mood*) differentially influenced actual brace-wearing for the group. However, in support of hypothesis three, the pattern of subjective brace-wear during events was different. The environmental variable of *praying and worshipping* and the intrapersonal variables of *competence,* and *negative mood* did not influence brace-wear, but being *comfortable*, and *passive activities* did.

Table 9

Logistic Analysis of Causal Effects of Subjective Brace-wearing and Not Brace-wearing

	Brace worn = 1		Brace not worn = 1	
	Odds Ratio	95% CI	Odds Ratio	95% CI

Environmental				
Physical activity	.17***	.07 - .41	5.58***	2.42 – 14.19
Study at school	22.67***	2.35 – 218.65	.04	.004 - .42
Studying not in school	.46	.03 – 7.60	2.19	.13 – 36.53
Riding in car/bus	.64	.27 – 1.52	1.56	.66 – 3.68
Socializing	1.41	.62 – 3.20	.71	.31 – 1.61
Talking on phone	1.44	.47 – 4.45	.70	.22 – 2.14
Eating	.79	.25 – 2.49	1.25	.40 – 3.93
Hygiene	.05***	.01 - .24	18.39***	4.13 – 81.87
Praying/worshipping	3.57**	1.28 – 10.00	.28**	.10 - .78
Passive activity	2.00**	1.01 – 3.99	.50**	.25 - .99
Work/chores	.51	.13 – 2.09	1.94	.48 – 7.95
Other activities	.73	.42 – 1.29	1.36	.77 – 2.40
Interpersonal				
Parents	.55	.16 – 2.07	1.82	.48 – 6.85
Brother/sister	.84	.41 – 1.73	1.19	.58 – 2.44
Friends at school	7.45**	2.09 – 28.60	.13**	.03 – .48
Friends not at school	1.19	.44 – 3.22	.84	.31 – 2.27
Peers not at school	1.02	.42 – 2.49	.98	.40 – 2.38
Adults at school	1.39	.11 – 1.39	2.52	.72 – 8.81
Adults not at school	.32***	.15 - .69	3.13***	1.45 – 6.75
Intrapersonal				
Comfortable	1.78*	.93 – 3.40	.56*	.29 – 1.08
Positive mood	.96	.82 – 1.12	1.04	.89 – 1.21
Negative mood	.88	.74 – 1.06	1.13	.94 – 1.35
Competence	1.00	.76 – 1.33	1.00	.75 – 1.34
Tired	1.15	.69 – 1.91	.87	.52 – 1.45
Impatient	1.11	.81 – 1.53	.90	.65 – 1.24

*p=.1, ** p = .05, *** p < .01

Note: odds ratios for individual participant dummy variables increased the odds of not wearing their brace and were not reported

The subjective reasons the participants gave for not wearing their brace during 156 episodes are shown in Table 10. The frequencies do not total the number of events the brace

was not worn because the participants were allowed to choose more than one option. The most frequently selected reason for not wearing their brace was *do not have to wear*, followed by *uncomfortable* and *restricted movement*. The adolescents provided reasons for not wearing their brace 137 times, but indicated 'other reasons' (reasons which were not listed on their response options) 94 times. In fact, 36 of the times they selected *other reasons* they selected one other reason, and for one adolescent, two other reasons were selected, but for 57 events *other reasons* was the only one selected.

Table 10

The Frequency and Number of Cross-reported Reasons for Not Wearing The Brace

	Total	*Do not have to wear*	*Uncomfortable*	*Restricted movement*	*Clothing did not fit or look right*	*Forgot*	*Didn't want others to know*	*Other reasons*
Do not have to wear	55	·	0	0	0	0	0	30
Uncomfortable	33	0	·		11	0	1	6
Restricted movement	24	0	22	·	10	0	1	1
Clothing did not fit or look right	13	0	11	10	·	0	2	1
Forgot	10	0	0	0	0	·	0	0
Didn't want others to know	2	0	1	1	2	0	·	0
Other reasons	94	30	6	1	1	0	0	·

Group Analyses of Distal Measures

Hypothesis 4. It was hypothesized that adherence would be associated with expectation of treatment success, functioning/activity levels, pain levels, satisfaction with self-image/appearance, mental health, and satisfaction with management of condition. The analyses reported below indicate support for this hypothesis.

The adolescents' quality of life and expectations about wearing the brace appear unremarkable. When compared with published means with a one sample *t*-test, the adolescents' scores on the SRS-22r did not differ significantly on the subscales for

functioning, pain, self-image, mental health, or satisfaction with management from a sample of adolescents with scoliosis (Glattes et al., 2007). On the PODOMS Expectations for Treatment Subscale, the adolescents as a group indicated they were not sure that wearing the brace would improve their current functioning (M = 3.11, SD = 1.6), but they expected wearing the brace would probably improve their functioning in the future (M = 3.91, SD = 0.89). In addition, the adolescents rated feeling neither positively nor negatively about how they felt about spending the rest of their life with their bone and muscle condition as it is now (M = 3.4, SD = 1.30).

A bivariate correlational analysis was conducted using the pre-study measures of quality of life and treatment expectations, and the objective brace-wear rate (total percentage of time in brace) for all participants. A trend was evident that high expectation for benefits from treatment was surprisingly associated with not wearing the brace ($p < 0.1$). Although current and future expectations subscales are negatively associated with brace wear, only the association with current expectation of benefits was statistically significant see (Table 11). A trend was evident, consistent with the original hypothesis that *functioning, pain, self-image,* and *mental health,* were associated with wearing their brace ($p < 0.1$). However, *satisfaction with management* was not associated with brace-wear. In sum, higher quality of life was associated with more brace-wearing, but satisfaction with management was not.

Table 11
Correlations for Global Measures Associated with Actual Adherence

	R
Functioning	.74*
Pain	.68*
Self-image	.90*

Mental health	.67*
Satisfaction with management	.37
Expectation for treatment	-.58*
Current	-.57*
Future	-.42

Discussion

The hypotheses for this investigation were mostly supported. Hypothesis one did identify environmental, interpersonal, and intrapersonal stimuli that influenced brace-wearing. Actual brace-wearing was influenced by the environmental stimuli of *being at 'school* and intrapersonal stimuli of *feeling competent,* and not wearing was influenced by environmental stimuli of *physical activities,* and *hygiene*, the interpersonal stimuli of *non-related adults when not at school, parents*, and the intrapersonal stimuli of *negative mood*. *Pain,* and *fatigue* did not influence brace-wearing. It should be noted that *hygiene* being influential is not surprising, since adolescents are instructed to take their brace off while bathing and showering.

Similarly, hypothesis two was supported. *Physical activity* and presence of *non-related adults* were influential in not wearing their brace in more than one of the individual regression analyses, but several variables, such as *studying at school*, were too highly correlated with brace-wearing to be retained within the regression models. Correlational analysis showed that *physical activity, non-related adults, parents*, and being *tired* were associated with not wearing their brace for more than one adolescent, and *studying at school,* being with *friends at school*, and *eating* were associated with wearing their brace. For some of the adolescents, unique variables, such as *siblings, negative mood*, and *passive activities* were associated with not wearing their brace. Other variables were associated for some and not associated for others. These findings highlight that even though variables may

be influential across participants when other variables are held constant, for individual adolescent patients, their unique barriers to brace-wearing should be assessed.

Hypothesis three was partially supported. Objective reports differed significantly from some subjective reports of brace-wear, and the patterns of causal effects differed. Distal reports of brace-wear reported by the participants at the beginning of the study overestimated the amount the participants wore their brace by an average of 11.4% for the sample, and as much as 18.7% or 4.4 hours for one adolescent, but more proximal daily reports by adolescents did not significantly differ from objective measures. The pattern of causal effects for subjective reports of wearing the brace differed slightly from the objective measure of whether the adolescent was wearing the brace during events. Although influential to the objective measures, the intrapersonal variables of *competence* and *negative mood* were not influential to the subjective measures. Instead the environmental variables of *praying and worshipping*, and *passive activity*, interpersonal variable of being with *friends at school*, and the intrapersonal variable of being *comfortable*, were. The discrepancies may be because during more emotionally negative events, adolescents may not have been aware of not wearing their brace or may have been reluctant to admit to not wearing it. The findings highlight the change in predictors when brace-wear is subjectively reported.

In support of hypothesis four, the functioning, pain, self-image, mental health subscales of the SRS-22r were significantly associated with brace-wear. Adolescents were more likely to wear their brace if they had better physical functioning, self-image, and mental health, and less pain. Contrary to hypothesis four, higher expectation of benefits from treatment was associated with less brace-wear. Therefore, the hypothesis is only partially supported. Specifically, the more current benefits they expected to receive from

brace-wear, the less likely they were to wear it. It may be speculated that the more adolescents wear their brace, the better they function physically and emotionally so they do not expect additional short-term benefits. Those who wear their brace less appear to function worse physically and emotionally and so continue to hope for more benefits from brace-wearing. This unexpected finding supports the difficulty with the use of distal measures for investigating adherence, because the direction of association with participants' ratings can be uncertain.

Contributions to Literature

Some of the findings in the current investigation are consistent with other investigations, in particular, the finding that brace-wearing was associated with problems during physical activities and flexibility (Andersen et al., 2002; Korovessis et al., 2007) and the association between brace-wearing and self-esteem (Lindeman & Behm, 1999) and self-efficacy (Morton et al., 2008). Although this study did not explicitly evaluate self-efficacy, the responses of the adolescents in this study to the query, how 'competent/capable' they were at the time, could be conceptualized as a proximal measure of their self-efficacy, consistent with Bandura's (1995) definition of self-efficacy as "people's beliefs in their capabilities to manage environmental demands" (p. 1). In addition, our finding that adolescents are more likely to wear their brace at school conflicts with some studies (Lou et al., 2002) but not with others, which found brace-wearing is more consistent during the school year (Edgar, 1998).

Some more of the findings in the current investigation are inconsistent with those of other investigations. First, in contrast to studies in which pain was associated with non-adherence to brace-wearing (Andersen et al., 2002; Korovessis et al., 2007), our findings are

inconclusive. For some individuals in our study, proximal reports of pain were associated with not wearing their brace, for others with wearing it. Proximal reports of pain were associated with brace-wearing for the subjective report of brace-wearing, but not when brace-wearing was objectively measured. Similarly, although the subscale for pain in the SRS-22r, which is a more distal report of pain, was associated with less brace-wearing, the direction of the association requires clarification. It may be that those adolescents who wore their brace less experience more pain as a result, or it may be that wearing the brace more may improve both their back condition and comfort with the brace.

Secondly, in contrast to a recent finding that brace-wear was associated with treatment expectancy as assessed by the questionnaire of pretreatment belief (Morton et al., 2008), in the current study treatment expectancy as assessed by the PODMS and measured during treatment was in fact negatively related to brace-wear. However, our findings may be related to the results of other studies (Charron-Prochownik et al., 2001) that found when patients adhere, their functioning is improved and their belief about the disorder changes. In the present investigation, when the adolescents adhered, they may have increased their functioning and reduced their pain, which may have reduced expectancy of more current treatment benefits. Therefore, the time point at which treatment expectancy is measured may strongly influence its association with brace-wear adherence. Although not possible in the current investigation, it would have been preferable to assess treatment expectancy prospectively, prior to implementation of bracing.

An alternative explanation for the unexpected finding that treatment expectancy was negatively related to brace-wearing is related to the age of the adolescents in this study. Younger adolescents, who therefore have lesser ability to use formal operations, may have

less ability to abstract across time. This limited ability to abstract across time has been suggested by some investigators as affecting adolescents' adherence to cancer medications (Tamaroff, Festa, Adesman, & Walco, 1992). Thus, younger adolescents may have difficulties realistically evaluating the future that may affect both their current behavior and their ability to extrapolate to future benefits of adherence.

Further, interpersonal variables associated with brace-wearing in the present study differed from those seen in some previous investigations. Although being with friends has been found to be a risk factor for not wearing their brace (Andersen et al., 2002), the current investigation suggests this is not the case. Finally, in contrast to prior research demonstrating an association between non-adherence and the presence of the opposite sex or intimate relationships (Andersen et al., 2002), the current investigation did not find such an association, possibly an artifact of the age range of adolescents in the current investigation who were well below 16 years old.

Surprisingly, our findings suggest parents and non-related adults constituted risk factors for non-adherence, even after accounting for physical activities, such as sports. Possible explanations for this finding may rest in parenting style, which this investigation did not assess. Parental responses to illness behaviors, such as complaints of pain, vary from being protective (e.g., allowing escape from discomfort) to encouraging and monitoring (e.g., work through the discomfort), and minimizing (Van Slyke & Walker, 2006). Parents who are protective may allow their children to remove the brace when they complain and parents who positively attend to complaints by reducing demands have the effect of increasing their children's illness behaviors (Walker, Claar, & Garber, 2002) in similar situations (e.g., their presence). Furthermore, children of more lenient parents adhere less

(Manne, Jacobsen, Gorfinkle, Gerstein, & Redd, 1993) and parents are more likely to overlook misbehavior of children who are perceived to be medically ill (Walker, Garber, & Van Slyke, 1995).

The differences between the findings in this investigation and the findings in previous investigations may also be due to the type of measures used, the timing of reports, and/or the perception of adherence. Participant recall may not be accurate (Marco et al., 1999; Menon, 1993) and indeed, this investigation demonstrated differences between influencing variables depending on whether brace-wear was objectively measured or subjectively reported by the participant. In addition, the inaccuracies increase with the more time that has gone by since the event (Marco et al., 1999). In contrast to one investigation that required the participant to recall several years after brace-wearing (Andersen et al., 2002), for this investigation, adolescents reported their brace-wearing and associated behaviors proximally in time, thereby, probably increasing the accuracy of participants' reports in this investigation. Finally in this investigation, adherence was interpreted to be linearly related to brace-wear, given that the amount of brace-wearing has a linear relationship to brace-effectiveness (Bowen et al., 2001; Katz & Durrani, 2001; Wiley et al., 2000; Yrjonen et al., 2007). In contrast, in previous studies, adolescents were often grouped according to adherence rates. For example, in two studies, high adherence was designated as wearing the brace more than 90% of the time prescribed, and poor adherence as wearing the brace less than 50% of the time prescribed (Helfenstein et al., 2006; Korovessis et al., 2007); in another, groups were classified as either 90 to 100 percent, 60 to 89 percent, 30 to 59 percent, or 30 to 7 percent adherent (Climent & Sanchez, 1999); in yet another study, participants were assigned to 'good' or 'bad' adherence groups by unknown criteria

(Wickers et al., 1977). Then the factors that affected their membership in a particular group were assessed and may differ from what are the risk factors for not wearing their brace regardless of group membership. For example, non-modifiable variables like age and gender often affect whether participants were adherent, but this investigation controlled for fixed non-modifiable variables and assessed risk factors for not wearing the brace, regardless of overall brace-wear duration.

In summary, the current investigation supports previous findings that brace-wearing is a problem during physical activities, more likely when adolescents have greater self-efficacy (i.e., feel 'competent/capable'), when they are studying in school, and, although the direction of the association is unknown, associated with the distal measure of self-esteem (personal regard of self). What the current investigation contributes to the literature is that parents and non-related adults are often present when adolescents are not wearing their brace, and negative mood is predictive of not wearing their brace. The unexpected findings regarding treatment expectancy in the current investigation also highlight the problems with making assumptions about the direction of causation when using distal cross-sectional reports instead of proximal longitudinal measures. The differences between the findings in this investigation and the findings in previous investigations may be due to using objective measures, proximal reports, and/or assessing associated variables influencing linear brace-wearing.

Ramifications of Non-adherence

Three or one third of the adolescents in this investigation wore their brace less than 18 hours per day, a rate associated with greater curve progression and need for surgery

(Wiley et al., 2000). Further one adolescent, who provided incomplete data, which were therefore not included in the statistical analysis, actually wore the brace less than five hours per day. Consistent with other studies (e.g., DiRaimondo & Green, 1988), a significant proportion of adolescents in the current study were wearing their braces less than the prescribed amount. Their reduced functioning in the short-term as seen on the SRS-22r sub-scales may result from their lack of brace-wear, which in turn may result in surgery down the road. Given the costs to the individual, third party payees, and medical community, intervention to increase brace-wearing is warranted.

Implications for Treatment

Adherence implies some volition by the participants, and the assumption of volition may be important for informing approaches to intervening to improve adherence. For example, the adolescents who inadvertently do not wear their braces long enough may benefit from problem-solving and educational approaches, including self-monitoring, whereas the adolescents who intentionally do not wear their braces long enough may benefit from interventions targeting their belief systems, such as therapeutic techniques of behavioral experimentation. Because the presence of non-relative adults and parents was consistently a significant predictor of not wearing the brace, it may be speculated that the adolescents might have had permission to keep it off. If this were the case, adolescents could thus have viewed themselves as actually following instructions and doing what they should have been doing and did not realize they were not wearing their brace long enough to be effective. Therefore, they may have been inadvertently not wearing the brace long enough to be beneficial, and treatments should likely target specific problem-solving and treatment-related education to prevent curve progression. In addition, given the implications

of parental involvement in adolescents not wearing their brace, intervention may require some sort of parent training and coaching of parent-child communication and parent-child collaborative problem-solving.

Behavioral Analytic Models

Several cognitive and cognitive-behavioral models of adherence behaviors were reviewed in the introduction and a strong argument was made for the use of the Behavioral Analytic Models to inform the current investigation. Designed to assess environmental, interpersonal, and intrapersonal variables associated with actual brace-wear, the results of the present investigation suggest several proximal variables are influential to brace-wearing.

In particular, one variable, self-efficacy during the event, as measured by the variable "competence/capable,' was found to influence brace-wearing, and some would argue that this finding would actually lend support to the cognitive models. To the contrary, however, Behavioral Analytic Models suggest that the events in which the adolescents felt 'competent/capable' are contextually similar to ones in which the adolescent had experienced positive consequences while wearing their brace in the past and expected to at the current time (e.g., good school performance). Therefore, self-efficacy is simply the adolescent's appraisal of the event as one in which they are likely to experience positive consequences while they wear their brace.

Another of the findings of this investigation, namely that proximal intrapersonal negative mood was uniquely predictive of less brace-wear, can be viewed from the behavior analytical perspective as an adolescents' appraisal of or response to an event. For example, good performance is necessary to do well when being physically active, especially when competing. Knowing or being told your performance is good (i.e., praise) can function an

internal or external reinforcer. In response to the inability to access the reinforcer (e.g., praise), a negative mood may result. Taking off the brace could be negatively reinforced by escape or avoidance of poor performance.

The demands of certain physical activities and hygiene appear to function as discriminative stimuli for non brace-wearing (behavior) by signaling when flexibility on good performance may result in praise (reinforcer). The results of the group interview in the preliminary investigation suggested that parents function as establishing operations, but the DRM data suggest parents and other adults act as discriminative stimuli, signaling the availability of reinforcers (e.g., praise for good performance) and the availability to escape from brace-wearing through giving permission to remove the brace. Matching Law appears to explain the greater likelihood of not wearing the brace as a result of most of the adolescents placing higher value on praise of good physical performance (reinforcers) during physical activities than on studying at school or passive activities.

In the present investigation, some of the adolescents were found to wear their brace too few hours per day to be effective. Conceptually, they may have generalized negative consequences experienced in one physical activity to other physical activities and may be not wearing the brace during activities in which the brace would actually not pose a problem (e.g., unorganized sports, games). Interventions to increase brace-wear, therefore, may involve leading adolescents to re-experience activities with their brace on to determine if it actually poses a problem.

Implications of Developmental Issues

Adolescents display unique patterns of adherence behaviors, likely the result of reinforcement values changing with increasing age. The adolescents in the current study

were under 16 years old, and most were not of dating age. For older adolescents, good appearance may be valued more highly and the influence of intimacy and the opposite sex variables on brace-wearing may be higher. In the current study, the parents were present during approximately 50% of the events when the adolescents were not at school, but in a sample of older adolescents, who are increasingly independent, parental presence may not affect brace-wearing as strongly. Similarly, it has been consistently shown that as adolescents get older and wear their brace for more years, their brace-wearing decreases (DiRaimondo & Green, 1988; Edgar, 1998; Gurnham, 1983; Korovessis et al., 2007; Takemitsu et al., 2004). Therefore, in older samples than that in the current study, the amount of adherence and the pattern of significant variables may be different.

Strengths of the Current Study

Assessment of both subjective and objective variables: This study is one of the first investigations to assess both objective brace-wearing and individual environmental, interpersonal, and intrapersonal causal effects of brace-wearing. Whereas it is true that objective measures of temperature and pressure have been used in several studies, almost none have also examined the psychosocial variables as this investigation did. A recent prospective investigation that did assess brace-wear both objectively and subjectively, did so for the purpose of validation of a pre-treatment cognitive and attributional assessment tool and what may be responsible for differences among physicians', technicians', parents', and patient's estimates of brace-wearing (Morton et al., 2008).

Using the DRM to assess psychosocial variables. A unique aspect of this study is the use of the DRM assessment method (Kahneman et al., 2004) for adherence behaviors. The DRM has been primarily used to assess satisfaction with life and happiness in one study

(Kahneman, Krueger, Schkade, Schwarz, & Stone, 2006) and pain in another study (Krueger & Stone, 2008), but has not been used to assess environmental, interpersonal, and intrapersonal variables influencing adherence. The present investigation employed the DRM method to retain the benefits of EMA while reducing the burden on the participants. Although the method does rely on participant recall, listing events in a sequential manner increased the accuracy of retrospective reports by promoting sequential and parallel retrieval (Belli, 1998). In addition, having the adolescents recall the events for only the last 24 hours, limited recency, saliency, and valence biases (Kahneman et al., 2004). To aid the adolescents with the task, in the present study a practice assessment was completed in the lab and the researcher was available by phone.

Proximal as opposed to distal measures. When reporting on proximal individual events using DRM, the adolescents in the current investigation were more accurate than their distal recall of brace-wearing. As a result of using the DRM method, one variable actually associated with not wearing their brace significantly differed from the reports during the preliminary group interview (i.e., presence of parents). Similarly, "not wanting others to know," which was identified in the group interview as a reason for not wearing the brace, was not associated with or often chosen in the DRM subjective report as a reason for not wearing the brace.

Flexibility of DRM Methodology. Another advantage of the DRM method in the present study was its flexibility to include the adolescents' language and concerns gathered during the preparatory group interview. Although the concerns and importance of the psychosocial influences of brace-wearing differed from those identified in the interview and those documented the daily DRM reports, this discrepancy highlights the importance of

using proximal rather than distal reports. The DRM method appeared well suited for assessing adherence behaviors and allowed each event to be assessed as a separate data point.

Compellingly, physicians are in need of better assessment tools that identify modifiable variables for patient adherence. Currently, medical professionals typically base their judgments of whether the patient is following instructions on patients' recall of distal events or other patient factors or behaviors, which, as discussed earlier in the *Design Issues* section, are shown to have flaws (Marco et al., 1999; Meehl, 1957; Menon et al., 1995; Rapoff, 1999; Rock et al., 1987). With further refinements, the DRM may be adapted for use by medical professionals to assist with identifying problematic situations for adherence for their patients. As seen in the preparatory investigation, patients may provide anecdotal information that may not accurately portray the frequency of events during which they wear or do not wear their brace. It is not necessary to complete the questionnaire on the handheld computer; the original version of the DRM (Kahneman et al., 2004) uses paper-and-pencil. Medical professionals may utilize an internet or email delivered version. Computerized scoring may also reduce the time required to analyze the data. Patients could complete the questions in the office for the previous 24 hours or, to increase the breadth of incidents reported, patients could complete the questionnaires for a few days at a time in between appointments.

Longitudinal single-case design. Another unique contribution of this study is that in contrast to the usual cross-sectional design of studies using the DRM and those investigating psychosocial variables associated with adherence, this study required the adolescents to

report on several randomly cued days to allow for the stability of performance, thereby reducing the possibility of spurious results. The multiple reports over several days provided sufficient data points to use robust regression procedures to analyze variables across participants, which identified several environmental, interpersonal, and intrapersonal variables influential to brace-wearing even after removing variance for the individuals and other variables.

In addition, the 47 to 81 (M = 65) data points for each adolescent in the present study allowed for regression analysis and correlational analysis *within* participants as well. This allowed for the evaluation of variables that may be significant for some adolescents, but not the majority, and may have clinical utility for assessing idiosyncratic barriers for individual patients, such as shopping, riding in vehicles, discomfort, and eating.

Limitations

As this is the first investigation of its kind, problems are to be expected and the current investigation is limited by the loss of usable data. DRM data from two participants were lost due to equipment failure or participant factors (i.e., not completing questions properly). For one of these two adolescents, the objective measure of brace-wear was available and reported within the group analyses in Table 8. The remaining nine participants represented a diverse and representative group (i.e., three ethnic identities, male and female, multiple suburban cities) and provided enough data for across participant analyses.

The single adolescent who did not complete the questions properly also illuminates another problem with investigations of adherence. Individuals who do not follow medical instructions are also less likely to follow research instructions. Indeed, the adolescent who did not complete the questions properly had the lowest overall brace-wear rate as measured

by the monitor (4.5 hours per day) yet the greatest distally reported brace-wear rate (100%). The current investigation was not able to include the important information concerning variables associated with brace-wear for the person with the greatest difficulties in adhering.

Future investigations

Future investigations should replicate the current investigation with more adolescents, as it cannot be certain that the findings from this unique investigation will generalize to other populations. In addition, the effects of sleep and time of day were not evaluated in this investigation and may warrant future investigation. Further, lagged relationships may provide additional information about events preceding brace-wear or removal, especially during the events where the participants "put on" or 'took off' their braces. Although qualitatively the adolescents did not report any problems with the electric monitoring system, explicitly and systematically asking participants about concerns with the monitoring system could increase confidence in the lack of reactivity to the system components in future investigations.

In future investigations, participants should be required to qualitatively specify reasons for removing their brace if the actual reason operating does not appear on the pre-established response-options specified in the study protocol. In the current investigation, the adolescents provided reasons for not wearing their brace 137 times, but indicated 'other reasons' (reasons which were not listed on their response options) 94 times. For approximately 40% of times they selected 'other reasons' they also selected one other reason, but for the remaining 57 events 'other reasons' was the only one selected. Although the reasons this investigation provided in the response options were the reasons the adolescents and their parents suggested during the preparatory investigation, obviously

several other reasons could also play a role. It may be that the adolescents' reasons are semantically different. For example, they may not select *uncomfortable* if their brace was *too hot.* Capturing the range and nature of adolescents' perceptions of those *other reasons* is important and should be investigated further.

Furthermore, the discrepancies between variables associated with objectively measured and subjectively reported brace-wear should be examined further. If future studies also find that discrepancies between proximal self-report and objective measures are small, these investigations may thus support the inference that proximal subjective reports of brace-wear alone may be adequate. If objective measures are thus shown to be not necessary, future research would incur less expense and data loss due to equipment failure.

Future studies should consider delivering the DRM questionnaire via email and the internet. Doing so would provide access to a larger sample pool. Furthermore, for some surveys, data would be available immediately so problems with completing the questionnaires could be addressed during the study rather than discovered afterwards. With a larger sample pool, fewer assessment points over time would be needed, further reducing participant burden, and permitting the examination of differences for fixed factors, such as age and gender. If measures of actual brace-wearing prove to be still necessary, temperature probes provide adequate information about whether the adolescent is wearing the brace. In addition, strap tension may be a more stable measure than pressure and may provide better measures of effective wear.

Conclusion

Using the modified DRM to assess variables associated with actual brace-wear within the framework provided by Behavioral Analytic constructs provided the information

that adolescents did not wear their braces when participating in *physical activities,* when with *parents* and *non-related adults,* during *hygiene* activities, and when in a more *negative mood.* As a group, the adolescents in this study were more likely to wear their brace when they were *studying at school* and when they felt *competent.* For individuals, other variables, such as *riding in vehicles, eating, shopping,* and *comfort* were associated with not wearing their brace and might be important additional idiographic risk factors. The main discrepancies between objective and subjective measures were intrapersonal situations in which the adolescents were less likely to report not wearing their brace when in a more 'negative mood' but were more likely report not wearing it when they were *uncomfortable.* Adolescents' subjective report of brace-wearing significantly over-reported wearing compared to the objective data when the subjective report was distal, i.e., when they estimated their adherence at the beginning of the study. Although general *functioning/activity, pain levels, self-image,* and *mental health* were associated with brace-wearing, the direction of the association cannot be determined, because more brace-wearing may produce better quality of life. The causal relationship is even more complicated when the adolescents who wore their brace more had lower expectations of current benefits. Importantly, this investigation was successful at pioneering a replicated single-case design to assess both objectively measured brace-wearing and environmental, interpersonal, and intrapersonal psychosocial variables using the DRM method and analyzed the results within and across participants.

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Footnotes

[1] DRM questionnaire available

www.sciencemag.org/cgi/content/full/306/5702/1776/DC1

APPENDICES

Appendix A: Group Interview

Thank you for participating in this research project. I would like you to answer the questions that I will be asking as thoroughly as possible and to the best of your ability. There are no right or wrong answers, and all your responses will be kept confidential (except as previously discussed in the Assent Form). Before we begin, do you have any questions?

General

1. How do you feel in general about wearing a brace for your back?
2. What makes wearing your brace difficult?
3. What makes wearing your brace easier?
4. When do you not like wearing your brace?
5. When do you like wearing your brace?
6. When have you tried to keep your brace hidden?
    a. Who were you with and what situations were you in?
7. What are some of reasons that you may not want to wear your brace when you are supposed to?
8. What are some of reasons that you may want to wear your brace when you are supposed to?

Environments

9. What makes it difficult to wear your brace when you are at home?
10. What makes it easier to wear your brace when you are at home?
11. What makes it difficult to wear your brace when you are at school?
12. What makes it easier to wear your brace when you are at school?
13. What other places is wearing your brace difficult?
    a. What makes it difficult to wear your brace at [place]?
14. What other places is wearing your brace easy?
    a. What makes it easy to wear your brace at [place]?

Interpersonal factors

15. In which ways do your parents make it harder for you to wear your brace?
16. In which ways do your parents make it easier for you to wear your brace?
17. In which ways do your brothers or sisters make it harder for you to wear your brace?
18. In which ways do your brothers or sisters make it easier for you to wear your brace?
19. In which ways do your friends make it harder for you to wear your brace?
20. In which ways do your friends make it easier for you to wear your brace?
21. In which ways do other teens your age make it harder for you to wear your brace?
22. In which ways do other teens your age make it easier for you to wear your brace?
23. In which ways do your teachers make it harder for you to wear your brace?
24. In which ways do your teachers make it easier for you to wear your brace?
25. Are there any other people that make wearing a brace difficult?
    a. In which ways does [person] make wearing your brace difficult?
26. I know I asked this question in the beginning, but have you thought of any other reasons you may not want to wear your brace when you are supposed to that we have not talked about?
27. What would help you wear your brace more often?

Appendix B: Background Questionnaire

PART A: BACKGROUND INFORMATION AND HOME RESOURCES

1. I am the patient's (check **all** that apply)

O Natural parent
O Adopted parent
O Foster parent
O Grandparent
O Step parent
O Legal Guardian
O State assigned custodian
O Other (describe)_____

2. **Your** gender: O Male O Female
3. Your child's gender: O Male O Female
4. **Your** age in years _____
5. Your child's age in years: _____
6. **Your** ethnic background (check **all** that apply)

O White/European American
O Black/ African American/African
O Spanish/Hispanic/Latino
O Asian/Pacific Islander/Asian Indian
O Native American Indian/Alaskan Native/Indigenous
O Middle Eastern
O Other _____

7. **Your child's** ethnic background (check **all** that apply)

O White/European American
O Black/ African American/African
O Spanish/Hispanic/Latino
O Asian/Pacific Islander/Asian Indian
O Native American Indian/Alaskan Native/Indigenous
O Middle Eastern
O Other _____

8. Which language(s) is spoken in the home _____
9. Your country of birth? O USA O Other, please specify: _____

   Your child's country of birth? O USA O Other, please specify: _____

10. **Your** current marital status

O Never married
O Now married
O Divorced
O Separated
O Living with partner
O Widowed

11. Are you the child's primary caregiver? O YES O NO

    If **NO**, who is your child's primary caregiver? _____

    What is their relationship to your child?_____

12. Which statement best describes your and your child's current housing situation?

O Own home O Rent O Live in relative's home
O Live in friend's home O Other, please specify: _____

13. How many bedrooms does the home/apartment have? _____

14. How many adults, including yourself, are *currently* living in your household? _____

15. How many children are *currently* living in your household, including the child whom you are bringing for services today? _____

16. How many adults in the household work and bring home money? _____

17. How many children in the household receive child support? _____

18. How many people in the home are receiving government support (for example public assistance/ welfare, SSI, unemployment, food stamps, WIC, AFDC, disability)? _____

19. What is your annual household income **now**?

O	Less than $10,000	O	$50,000 to $74,999
O	$10,000 to $24,999	O	$75,000 to $99,999
O	$25,000 to $49,999	O	$100,000 or more

PART B: MEDICAL INFORMATION

20. Please indicate how many of each type of medical visit your child has had in the past 6 months:

a. Spine-related scheduled medical visits
O **0** O **1 - 3** O **4 - 8** O **9 or more**

b. Other scheduled medical check-ups (for example- well child, sports physical)
O **0** O **1 - 3** O **4 - 8** O **9 or more**

c. Unplanned medical appointments for other problems (for example- flu symptoms, asthma attacks)
O **0** O **1 - 3** O **4 - 8** O **9 or more**

d. Emergency room visits for any problem
O **0** O **1 - 3** O **4 - 8** O **9 or more**

21. How many days has your child been hospitalized **in the past 6 months?**
O **0** O **1 - 3** O **4 - 8** O **9 or more**
For what conditions? _____

22. Does your child have other chronic medical conditions requiring medical treatment? O YES O NO
If YES**,** please list (e.g., obesity, epilepsy, diabetes, etc.): _____

23. Has your child been diagnosed with a behavioral or psychological condition requiring treatment?
O YES O NO
If YES**,** please list (e.g., ADHD, depression, anxiety, conduct disorder, etc.):_____

25. Does your child currently have health insurance? O YES O NO

26. What type of health insurance does your child currently have?

O Medicaid	O Medicare/HMO	O HMO
O POS	O PPO	O Traditional (indemnity)
O Not sure	O Other, please specify: _____	

27. Has your child's health insurance changed in the last 6 months? O YES O NO

If YES, why? _____

28. Do you pay your child's insurance premiums yourself?
O YES O NO O Partia

29. How much do you worry about being able to afford your child's premiums?
O Not at all O A little O Some O A lot O Very much

30. How do you worry about your child being insurable?
O Not at all O A little O Some O A lot O Very much

31. How difficult is it for you to afford your child's deductible amounts?
O N/A O Not at all O A little O Some O A lot O Very much

32. How difficult is it for you to afford your child's co-pay amounts?
O N/A O Not at all O A little O Some O A lot O Very much

33. Do you require referrals for your child's back problems? O YES O NO O Unsure
If YES, how difficult is it for you to obtain your child's medical referrals?
O Not at all O A little O Some O A lot O Very much

34. How much have difficulties with health insurance affected your ability to keep your child's medical appointments?
O Not at all O A little O Some O A lot O Very much

35. How much have difficulties with health insurance made your child's condition worse?
O Not at all O A little O Some O A lot O Very much

36. How much have difficulties with transportation affected your ability to keep medical appointments?
O None O A little O Some O A lot O Very much

37. How much difficulty did you have **today** with transportation?
O None O A little O Some O A lot O Very much

38. Are there other children in the home who require more than routine medical care? O YES O NO
If YES, for what conditions?_____
If YES, how many medical visits did he or she have in the in the past 6 months?
O **0** O **1 - 3** O **4 - 8** O **9 or more**

39. Are there other children in the home who have been diagnosed with a behavioral or psychological condition requiring treatment? O YES O NO
If YES, for what condition(s)?_____

40. Are there any adults in the home who require more than routine medical care? O YES O NO
If YES, for what condition(s)?_____
If YES, how many medical visits did he or she have in the in the past 6 months?
O **0** O **1 - 3** O **4 - 8** O **9 or more**

41. Are there other adults in the home who have been diagnosed with a behavioral or psychological condition requiring treatment? O YES O NO
If YES, for what condition(s)?_____

42. How likely are you and/or your child to: (circle the number that best applies)

	None of the time			Some of the time			All the time
a. Use braces as prescribed	1	2	3	4	5	6	7
b. Keep all medical appointments	1	2	3	4	5	6	7
c. Follow activity restrictions	1	2	3	4	5	6	7

43. During the last week, how many hours per day was your child prescribed to wear their brace? _____

44. During the last week, how many hour per day did your child wear their brace? _____

45. Do you know anyone who currently has or once had scoliosis? O YES O NO
If YES, which treatment did he or she receive for his or her back problem? (check **all** that apply)
O Bracing O Surgery O Not known

46. How have you researched your child's back problem (check **all** that apply)
O Internet
O Library
O Family
O Friends
O Other _____

PART C: EDUCATION AND EMPLOYMENT INFORMATION

47. How far did you get in school?
O Grade 7 to 11
O Graduated high school or GED
O Some college credits
O Graduated 2-yr degree or certificate program
O Graduated 4-yr college
O Completed graduate/professional school

48. What was your major in college? _____

49. What is your employment status? (check **all** that apply)
O Full-time (40 hrs/wk or more)
O Part-time
O On disability
O Retired (on social security)
O Student
O Self-employed
O Homemaker
O Receiving public assistance/welfare
O Receiving supplemental security income

50. If you are **currently working**, what type of work do you do: _____
(e.g., secretary, heating and cooling technician, teacher, manager, etc.)

51. If you are **currently working**, how many workdays have you missed **in the past <u>6 months</u> due to your child's health problems**?
O None
O 1-5 days
O 6-10 days
O 11-20 days
O 21-30 days
O 31-40 days
O more than 40 days

52. If you are **currently working**, how many workdays have you missed **in the past <u>4 weeks</u> due to your child's health problems**?
O None O 1-5 days O 6-10 days O 11-15 days O 16-20 days

Answer the next 3 questions about you child's other parent. If yours is a blended family, select biological parent or stepparent who is most involved in your child's life.

53. How far did your child's other parent get in school? O Do not know
O Grade 7 to 11
O Graduated high school or GED
O Some college credits
O Graduated 2-yr degree or certificate program
O Graduated 4-yr college
O Completed graduate/professional school

54. If he/she went to college, what was your child's other parent's major in college? _____

55. What is your child's other parent's employment status? (check **all** that apply) O Do not know
O Full-time (40 hrs/wk or more)
O Part-time
O On disability
O Retired (on social security)
O Student
O Self-employed
O Homemaker
O Receiving public assistance/welfare
O Receiving supplemental security income

56. If he/she is **currently working**, what type of work do your child's other parent do:

_____

PART D: YOUR CHILD'S EDUCATIONAL AND RECREATIONAL ACTIVITIES

57. Can your child participate in recreational outdoor activities with other children the same age?
(For example: bicycling, skating, hiking, jogging)
O Yes, easily O Yes, but a little hard O Yes, but very hard O No
If you answered "no," was your child's activity limited by: (check all that apply)
O Pain?
O General Health?
O Doctor or parent instructions?
O Fear the other kids won't like him/her?
O Dislike of outdoor recreational activities?
O Activity not in season?

58. Can your child participate in pickup games or sports with other children the same age?
(For example: tag, dodge ball, basketball, soccer, catch, jump rope, touch football)
O Yes, easily O Yes, but a little hard O Yes, but very hard O No
If you answered "no," was your child's activity limited by: (check all that apply)
O Pain?
O General Health?
O Doctor or parent instructions?
O Fear the other kids won't like him/her?
O Dislike of outdoor recreational activities?
O Activity not in season?

59. Can your child participate in competitive level sports with other children the same age? (For example: hockey,
basketball, soccer, football, baseball, swimming, running track or cross country, gymnastics, or dance)
O Yes, easily O Yes, but a little hard O Yes, but very hard O No
If you answered "no," was your child's activity limited by: (check all that apply)
O Pain?
O General Health?
O Doctor or parent instructions?
O Fear the other kids won't like him/her?
O Dislike of outdoor recreational activities?
O Activity not in season?

60. During the last year, which type of school has your child attended?
O Public school O Private school O Home school O Other _____
61. What grade is your child in? (if the child is between grades, which one will he/she be in) _____
62. Does your child receive extra assistance (or special services) in the classroom?
O All of the time O Some of the time O None of the time

63. How many school days has your child missed **in the past <u>6 months</u>** due to his or her health problems?
O None O 1-5 days O 6-10 days
O 11-20 days O 21-30 days O 31-40 days O more than 40 days

Appendix C: Modified Scoliosis Research Society-22R Patient Questionnaire

We are carefully evaluating the condition of your back, and it is important that you answer each of these questions yourself.

Please mark the one best answer to each question. If you are unsure about how to answer a question, please give the best answer you can.

Q1 Which one of the following best describes the amount of pain you have experienced during the past 6 months?

- ❑ *None*
- ❑ *Mild*
- ❑ *Moderate*
- ❑ *Moderate to severe*
- ❑ *Severe*

Q2 Which one of the following best describes the amount of pain you have experienced over the last month?

- ❑ *None*
- ❑ *Mild*
- ❑ *Moderate*
- ❑ *Moderate to severe*
- ❑ *Severe*

Q3 During the past 6 months have you been a very nervous person?

- ❑ *None of the time*
- ❑ *A little of the time*
- ❑ *Some of the time*
- ❑ *Most of the time*
- ❑ *All of the time*

Q4 If you had to spent the rest of your life with your back shape as it is right now, how would you feel about it?

- ❑ *Very happy*
- ❑ *Somewhat happy*
- ❑ *Neither happy nor unhappy*
- ❑ *Somewhat unhappy*
- ❑ *Very unhappy*

Q5 What is your current level of activity?

- ❑ *Bedridden*
- ❑ *Primarily no activity*
- ❑ *Light labor and light sports*
- ❑ *Moderate labor and moderate sports*
- ❑ *Full activities without restriction*

Q6 How do you look in clothes?

- ❑ *Very good*
- ❑ *Good*
- ❑ *Fair*
- ❑ *Bad*
- ❑ *Very Bad*

Q7 In the past 6 months have you felt so down in the dumps that nothing could cheer you up?
- ❑ *Very often*
- ❑ *Often*
- ❑ *Sometimes*
- ❑ *Rarely*
- ❑ *Never*

Q8 Do you experience back pain when at rest?
- ❑ *Very often*
- ❑ *Often*
- ❑ *Sometimes*
- ❑ *Rarely*
- ❑ *Never*

Q9 What is your current level of work/school activity?
- ❑ *100% normal*
- ❑ *75% normal*
- ❑ *50% normal*
- ❑ *25% normal*
- ❑ *0% normal*

Q10 Which of the following best describes the appearance of your trunk: defined as the human body except for the head and extremities?
- ❑ *Very good*
- ❑ *Good*
- ❑ *Fair*
- ❑ *Poor*
- ❑ *Very poor*

Q11 Which one of the following best describes your medication usage for your back?
- ❑ *None*
- ❑ *Non-narcotics weekly or less (e.g., aspirin, Tylenol, Ibuprofen)*
- ❑ *Non-narcotics daily*
- ❑ *Narcotics weekly or less (e.g., Tylenol III, Lorocet, Percocet)*
- ❑ *Narcotics daily*
- ❑ *Other Please specify*_____

Is usage: ❑ *Daily* ❑ *Weekly or less*

Q12 Does your back limit your ability to do things around the house?
- ❑ *Never*
- ❑ *Rarely*
- ❑ *Sometimes*
- ❑ *Often*
- ❑ *Very often*

Q13 Have you felt calm and peaceful during the past 6 months?
- ❑ *All of the time*
- ❑ *Most of the time*
- ❑ *Some of the time*
- ❑ *A little of the time*
- ❑ *None of the time*

Q14 Do you feel that your back condition affects your personal relationships?
- ❑ *None*
- ❑ *Slightly*
- ❑ *Mildly*
- ❑ *Moderately*
- ❑ *Severely*

Q15 Are you and/or your family experiencing financial difficulties because of your back?
- ❑ *Severely*
- ❑ *Moderately*
- ❑ *Mildly*
- ❑ *Slightly*
- ❑ *None*

Q16 In the past 6 months have you felt downhearted and blue?
- ❑ *Never*
- ❑ *Rarely*
- ❑ *Sometimes*
- ❑ *Often*
- ❑ *Very often*

Q17 In the last 3 months have you taken any sick days from work/school due to back pain, and if so, how many?
- ❑ *0*
- ❑ *1*
- ❑ *2*
- ❑ *3*
- ❑ *4 or more*

Q18 Does your back condition limit your going out with friends/family?
- ❑ *Never*
- ❑ *Rarely*
- ❑ *Sometimes*
- ❑ *Often*
- ❑ *Very often*

Q19 Do you feel attractive with your current back condition?
- ❑ *Yes, very*
- ❑ *Yes, somewhat*
- ❑ *Neither attractive nor unattractive*
- ❑ *No, not very much*
- ❑ *No, not at all*

Q20 Have you been a happy person during the past 6 months?
- ❑ *None of the time*
- ❑ *A little of the time*
- ❑ *Some of the time*
- ❑ *Most of the time*
- ❑ *All of the time*

Q21 Are you satisfied with the results of your back management?
- ❑ *Very satisfied*
- ❑ *Satisfied*
- ❑ *Neither satisfied nor unsatisfied*
- ❑ *Unsatisfied*
- ❑ *Very unsatisfied*

Q22 Would you have the same management again if you had the same condition?
- ❑ *Definitely yes*
- ❑ *Probably yes*
- ❑ *Not sure*
- ❑ *Probably not*
- ❑ *Definitely not*

Appendix D: Patient Expectations for Orthopedic Treatment Questionnaire

What expectations do you have for your treatment? As a result of your treatment, what do you expect? Put an X in the box that most closely states your expectation.

	Definitely yes	Probably yes	Not sure	Probably not	Definitely not
To have pain relief in my life now					
To look better					
To feel better about myself					
To be able to sleep more comfortably					
To be able to do more activities at home					
To be able to do more at school					
To be able to do more play or recreational activities (biking, walking, doing things with friends)					
To be able to do more sports					
To be free from pain as an adult					
To be free from disability as an adult					
To prevent the scoliosis from getting worse					
To prevent heart or lung problems					

If you had to spend the rest of your life with your bone and muscle condition *as it is right now*, how would you feel about it? Please circle your answer.

Very Satisfied	Somewhat satisfied	Neutral	Somewhat dissatisfied	Very dissatisfied

If your doctor prescribed a brace for you to wear, *how many hours each day* are you wearing the brace? _____

Appendix E: Diary Pages

The diary pages will ask you:
About what time did you go to sleep yesterday? _____

And what time did you wake up? _____

Then
On the next three pages, please describe your day --

- Think of your day as a continuous series of scenes or episodes in a film.
- There is a timeline drawn on the top to help you think about your day.
- Give each episode a brief name that will help you remember it (for example, “riding bus to school”, or “at lunch with B”).
- Write down the approximate times at which each episode began and ended.
- The episodes people identify usually last between 15 minutes and 2 hours.
- Indications of the end of an episode might be going to a different location, ending one activity and starting another, or a change in the people you are interacting with.

There is one section for each part of the day –

- Evening (from when dinner began yesterday until you went to sleep)
- Morning (from waking up until lunch began)
- Afternoon (from when lunch began to when dinner began today)

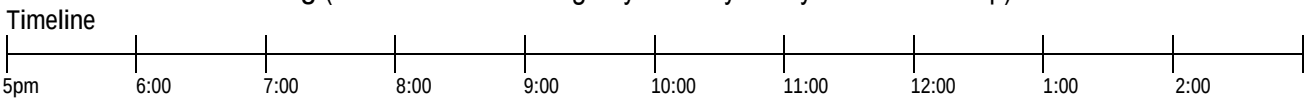
There is room to list 8 episodes for each of the 3 parts of the day—

- You may not need that many, depending on your day
- It is not necessary to fill up all of the spaces – use the breakdown of your day that makes the most sense to you and best captures what you did and how you felt.
- However if you can, try to make at *least 10 episodes* for the entire day.
- Try to remember each episode in detail, and write a few words that will remind you of exactly what was going on.
- Also, try to remember how you felt, and what your mood was like during each episode. What you write only has to make sense to you, and to help you remember what happened when you are answering the questions on the handheld computer.

Remember, what you write in your diary will not be seen by anybody else.
The diary pages are yours to keep if you wish – you don’t have to turn it in with the rest of your questionnaire.

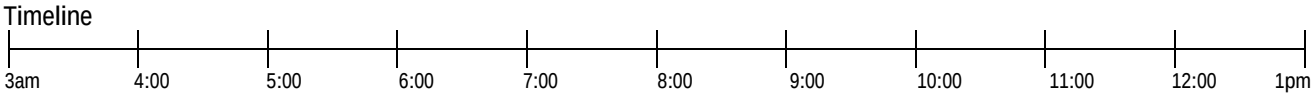
Diary Pages (abbreviated)

Evening (from when dinner began yesterday until you went to sleep)



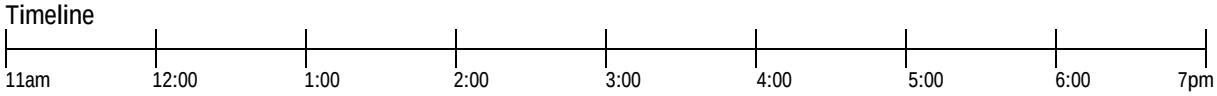
What happened? Episode Name	Time it Began	Time it Ended	Notes to yourself: What did you feel?
_Dinnertime__ 1rst Eve	_____	_____	_____
_____ 2nd Eve	_____	_____	_____
_____ 3rd Eve	_____	_____	_____

Morning (from waking up until lunch began)



What happened? Episode Name	Time it Began	Time it Ended	Notes to yourself: What did you feel?
_____ 1rst Morn	_____	_____	_____
_____ 2nd Morn	_____	_____	_____
_____ 3rd Morn	_____	_____	_____

Afternoon (from when lunch began until dinner began today)



What happened? Episode Name	Time it Began	Time it Ended	Notes to yourself: What did you feel?
Lunchtime 1rst Aft	_____	_____	_____
_____ 2nd Aft	_____	_____	_____
_____ 3rd Aft	_____	_____	_____

Appendix F: Daily Reconstruction Method for Brace-wearing

Before we proceed, please look back at your diary pages.

How many episodes did you record for the Morning? _____

How many episodes did you record for the Afternoon? _____

How many episodes did you record for the Evening? _____

Now, we would like to learn in more detail about how you felt during those episodes. For each episode, there are several questions about what happened and how you felt. Please use the notes on your diary pages as often as you need to.
Please answer the questions for every episode you recorded, beginning with the first episode in the Morning. To make it easier to keep track, we will ask you to write down the number of the episode that is at the beginning of the line where you wrote about it in your diary.

For example, the first episode of the Morning was number 1M, the third episode of the Afternoon was number 3A, the second episode of the Evening was number 2E, and so forth.

It is very important that we get to hear about all of the episodes you experienced yesterday, so please be sure to answer the questions for each episode you recorded.

After you have answered the questions for all of your episodes, including the last episode of the day (just before you went to bed), you can go on and select “last episode” and answer the questions about your sleep.

Appendix F: Daily Reconstruction Method

Daily Events/Episodes

Handheld Computer

#	Screen
1	Is this the first episode? Yes I No
2	Before we proceed, please look back at your diary pages. How many episodes did you record for for yesterday evening? Select one (list of numbers) this morning? Select one this afternoon? Select one
3	Please look at your Diary and select the earliest episode you noted yesterday evening.
4	When did this first episode begin and end? Please try to remember the times as precisely as you can. This is episode number Select one (list of numbers) In the Select one Evening Morning Afternoon which began at set time and ended at set time
5	What were you doing? (check all that apply)(1 of 5 pages) Riding in car/bus ☐ Studying ☐ Working ☐ Shopping ☐ Doing chores ☐ Talking on the phone ☐
6	What were you doing? (check all that apply) (2 of 5 pages) Socializing ☐ Dancing ☐ Swimming ☐ Eating ☐ Watching TV ☐ Using computer ☐ Napping/resting ☐
7	What were you doing? (check all that apply) (3 of 5 pages) Exercising ☐ Showering/bathing/hygiene ☐ Playing board games/cards ☐ Organized sports/games ☐
8	What were you doing? (check all that apply) (4 of 5 pages) Onorganized sports/games ☐ Praying/worshipping/meditating ☐ Special occasion (wedding, awards ceremony) ☐
9	What were you doing? (check all that apply) (5 of 5 pages) Intimate relations/kissing ☐ Other activity ☐

10 Where were you?
Home □
School □
Someone else's home □
Store/mall □
Work □
Somewhere else □

11 Were you interacting/talking with anyone (including on the phone, etc)?
Yes I No

12 Who were you talking with? (check all that apply)*
Parents/adult relatives □
Brother/sister □
Friends □
Boyfriend/girlfriend/partner □
Other teens/peers □
Other adults □

13 Was anyone else present?
Yes I No

14 Who was else was present? (check all that apply)*
Parents/adult relatives □
Brother/sister □
Friends □
Boyfriend/girlfriend/partner □
Other teens/peers □
Other adults □

15 During the episode, were you wearing your brace?
Select one
All of the time
Part of the time
Not at all

16 During the episode, did you put on or take off your brace?*
Select one
Put it on
Took it off
Both

17 Why did you take off or not wear your brace? (check all that apply) (1 of 2 pages)*
Uncomfortable □
Hard to move/bend/twist/get up/roll over □
Did not have to wear □
Trouble putting on □

18 Why did you take off or not wear your brace? (check all that apply) (2 of 2 pages)*
Forgot □
Clothing didn't fit or look right □
Didn't want others to know □
Other reason □

19 Why did you not want others to notice your brace? (check all that apply)
Embarrassed □
Did not want to have to explain □
Did not want others to think of me differently □
Other reason □

20 Why did you put your brace back on? (check all that apply)*
Uncomfortable □
Did not want to have to explain □
Scheduled time to put on □
Someone reminded me □

Other reason ☐

21 How comfortable was your brace or back at the time? Select one
Extremely uncomfortable
Very uncomfortable
Somewhat uncomfortable
Somewhat comfortable
Very comfortable
Extremely comfortable

22 What made your brace uncomfortable? (check all that apply)*
Too hot ☐
Skin or rubbing problems ☐
Poking ☐
Spine/rib/muscle pain ☐
Ate too much ☐
Other ☐

23 How did you feel during this episode? Please rate each feeling.

0 means that you did not experience that feeling at all.
6 means that this feeling was a very important part of the experience.
Please choose the number between 0 and 6 that best describes how you felt.

24 How did you feel during this episode? (1 of 2 pages)

Impatient for it to end Select one
Happy Select one
Frustrated/annoyed Select one
Depressed/blue Select one
Competent /capable Select one
Hassled/pushed around Select one
0 Not at all
1
2
3
4
5
6 Very much

25 How did you feel during this episode? (1 of 2 pages)

Warm/ friendly Select one
Angry/hostile Select one
Worried/anxious Select one
Enjoying myself Select one
Criticized/put down Select one
Tired Select one

26 Is this the last episode?

Yes I No

27 How many hours did you wear your brace during the last 24 hours?

+-	7	8	9
Del	4	5	6
00	1	2	3
	000	0	.

28 What time did you go to bed last night?**
set time
What time did you wake up this morning?**
set time

29 While you were sleeping, were you wearing your brace?**
Select one
All of the time
Part of the time
Not at all

30 During the nighttime, did you put on or take off your brace?*
Select one
Put it on
Took it off
Both

31 Why did you take off or not wear your brace while sleeping? (check all that apply) (1 of 2 pages)*

Uncomfortable ☐
Hard to move/bend/twist/get up/roll over ☐
Did not have to wear ☐
Trouble putting on ☐

32 Why did you take off or not wear your brace while sleeping? (check all that apply) (2 of 2 pages)*

Forgot ☐
Clothing didn't fit or look right ☐
Didn't want others to know ☐
Other reason ☐

33 Why did you not want others to notice your brace? (check all that apply)*

Embarrassed ☐
Did not want to have to explain ☐
Did not want others to think of me differently ☐
Other reason ☐

34 Why did you put your brace back on? (check all that apply)*

Uncomfortable ☐
Did not want to have to explain ☐
Scheduled time to put on ☐
Someone reminded me ☐
Other reason ☐

35 How comfortable was your brace or back during the night?

Select one
Extremely uncomfortable
Very uncomfortable
Somewhat uncomfortable
Somewhat comfortable
Very comfortable
Extremely comfortable

36 What made your brace or back uncomfortable? (check all that apply)*

Too hot ☐
Skin or rubbing problems ☐
Spine/rib/muscle pain ☐
Poking ☐
Ate too much ☐
Other reason ☐

37 Way to go!
Tap "End"
The computer will shut off by itself.
Remember to keep the computer plugged in

38 Select "End"
Then on the next screen tap "New" at the bottom of the screen to answer questions about the next episode