Supplementary Material

Table 1: characteristics of the participants in the collection of daily behaviors

Category	Attribute	Count
Gender	Male	25 (50%)
	Female	25 (50%)
Age Range	≤ 17	10 (20%)
	18-25	9 (18%)
	26-34	9 (18%)
	35-54	10 (20%)
	≥ 55	12 (24%)
Occupation	Students	Primary school students, Middle school students, High school students, Undergraduates, Master's students, PhD students
	Service Industry	Customer service representatives, Retail workers
	Workers	Logistics workers, Factory line workers, Construction workers
	Professionals	Finance/Accounting personnel, Engineers, Teachers/Professors, IT/Software developers, Doctors, Researchers, Lawyers
	Corporate Management	Junior managers, Middle managers, Senior managers (e.g., CEO, CTO)
	Government	Civil servants, Government officials
	Others	Retirees, Freelancers, Homemakers

1 Data Collection on Daily Behaviors

Task layers' elements corresponding to specific Needs Layers are: "Nourish" and "Repose" under **Physiological Needs**; "Work," "Study," "Housework," and "Exercise" under **Safety Needs**; and "Entertainment" and "Socialize" under **Social Needs**.

We conducted a systematic survey study to obtain a representative activity set that accurately reflects human daily behavior patterns. A total of 50 participants were recruited, consisting of 25 females and 25 males, from diverse age groups, occupations, and backgrounds. A total of 50 participants were recruited, consisting of 25 females and 25 males, whose ages ranged from 12 to 70 years ($M = 36.42, SD = 18.64$). The participants represented a variety of occupations, including students, those in the service industry, workers, professionals, those in corporate management, those in government, and others (retirees, freelancers, and homemakers). Our division of age groups is based on whether human domestic activities within that age range have a similar pattern. See characteristics of the participants in daily behavior collecting in Table 1. The objective was to gather comprehensive information on their daily home environment activities. The data collection process included both questionnaires and interviews, with the latter mainly targeting minors and elderly individuals who could not complete the questionnaires independently, ensuring the completeness and accuracy of the data.

During the data collection phase, we not only gathered basic demographic information such as gender, age, and occupation but also focused specifically on the specific activities that participants might engage in under eight major task categories. Participants were guided to recall their typical daily behaviors at home and to detail all possible activities for each task category. They were also encouraged to provide additional task types or activities that could not be categorized within the eight predefined task types. After data collection, we organized and analyzed the responses, extracting a comprehensive set of activities for each task category. The detailed data of participants' characteristics and extracted activity data are as follows:

The extracted activity data are summarized as follows:

```
{
    "Work": {Writing paper documents, Preparing
        electronic work materials, Reading files,
        Attending meetings, Coding, Responding to emails
        , Grading assignments, Communicating with
        colleagues, Doing homework, Preparing lessons,
        Writing papers},
    "Nourish": {Cooking, Ordering takeout, Snacking,
        Eating frozen and pre-made meals},
    "Repose": {Daydreaming while sitting, Taking short
        naps, Sleeping, Foot baths, Self-massaging with
        tools, Listening to music, Meditating},
    "Study": {Reading professional books, Watching
        educational videos, Watching science
        popularization videos, Coding exercises, Reading
         newspapers, Watching TV news, Listening to the
        radio, Doing practice questions, Reviewing for
        exams, Drawing practice, Reading research papers
        , Learning industry knowledge},
    "Housework": {Sweeping, Mopping, Hand washing clothes
        , Using robot vacuums, Making the bed, Tidying
        up rooms, Cleaning the desk, Watering plants,
        Washing dishes, Dusting furniture, Garden
        maintenance},
    "Exercise": {Doing aerobics, Bodyweight exercises,
        Running on the treadmill, Doing calisthenics,
        Dancing, Weightlifting, Practicing yoga, Riding
        stationary bikes, Playing fitness games, Jumping
         rope, Playing shuttlecock, Doing stretches},
    "Entertainment": {Watching TV shows, Watching movies,
         Watching anime, Drawing, Listening to music,
        Making tea, Playing mobile games, Playing
        computer games, Singing, Solving puzzles,
        Reading magazines, Listening to the radio,
        Drinking, Reading e-novels, Watching short
        videos, Watching live streams, Online shopping,
        Playing guitar, Playing violin, Playing piano},
    "Socialize": {Text chatting online, Video chatting,
        Voice calling, Group chatting online, Sending
        SMS}
}
```

2 Supplementary Explanation on the Usage of Multiple Factors in the World State

An example input of **Personality** information is as follows:

```
{
"Personality": "BigFivePersonality:'Openness'-'60', '
    Conscientiousness'-'60', 'Extraversion'-'60', '
    Agreeableness'-'60', 'Neuroticism'-'60'"
}
```

An example input of **Attributes** information is as follows:

```
{
"Background": "Male, 31 years old, 178 cm tall, 69 kg in
    weight, works as a chef, highest education level is
    high school graduate, enjoys eating gourmet food,
    dislikes exercising."
}
```

For **time** representation, we use the 24-hour format. For example: 09:00.

An example input of **Completed Activities**' event information, formatted and organized, is as follows:

```
{
"CompletedActivities": {
      "Event1": "from 09:00 to 09:06, in Room-{Kitchen}
          Place-[EatPlace], Task-<<Nourish>> Activity-<
          CookAndEat> Object-(cookingbench) Completed"
    }
}
```

For the representation of **3D Scene**, we define three main attributes that called "**SceneDescription**", "**AgentInfo**", and "**ObjectInfo**":

- **SceneDescription** describes the 3D scene information where the virtual human is situated. The scene structure is divided into three layers: the room layer, the place layer, and the object layer. These layers have hierarchical relationships, including room-to-place and place-to-object, and connectivity between place-to-place, indicating the navigability of walkable areas. An example of SceneDescription is as follows:

```
{
"SceneDescription": "The house has the room that is
    named {Kitchen}.In {Kitchen}, there is a place
    called [CookPlace]. In [CookPlace], there is
    one object called (cookingbench). In {Kitchen},
     there is a place called [EatPlace]. The house
    has a room named {LivingRoom}.In {LivingRoom},
    there is a place called [LivingPlace]. In [
    LivingPlace], one object is called (a phone).
    The connectivity information between places is
    as follows: The walking areas between [
    CookPlace] and [EatPlace] are interconnected. "
}
```

- **AgentInfo** and **ObjectInfo** provide specific spatial data of the 3D scene. Agent3DInfo indicates the current location of the virtual human (i.e., the names of the room and place within the scene), while Object3DInfo describes the navigable path distances between all objects in the room and the virtual human. We utilize the Navigation module in Unity to store path information and calculate specific distances. An example of this attribute is:

```
{
    "AgentInfo": "The character current in-room {
        Kitchen}, in place [CookPlace]",
      "ObjectInfo": {
        "(cookingbench)": "Path Distance:10.00m",
        "(phone)": "Path Distance:10.95m",
        "(computer)": "Path Distance:11.42m"
      }
}
```

Figure 1: Our implementation of DSG visualized in Unity. In the figure, various information within the DSG is visualized as follows: the dark blue panels correspond to **Room** Nodes, the gray panels represent **Place** Nodes, and the green panels represent **Object** Nodes. The dark blue Room areas are mostly covered by the gray Place blocks, making it difficult to display the color-block regions of the Room nodes in the figure. Yellow arrows indicate the containment relationships between Room-Place and Place-Object, where the starting point of the arrow is the parent node, and the endpoint is the child node contained within the parent. Cyan arrows represent the connectivity between **Place** Nodes.

For defining the dynamic change of **Needs** for LLM, we adopt the first three levels of Maslow's hierarchy of needs, with each need's intensity dynamically changing over time. The research by Yuan et al. captures the dynamic nature of needs, which primarily manifest as two dynamic processes: "Spontaneous Flow" and "Instantaneous Jump." Spontaneous Flow describes the continuous time variation of need intensity; for example, the need intensity for certain activities can accumulate if not engaged for a while and gradually diminish over time. Instantaneous Jump simulates the direct impact of activities on the need state; for example, the occurrence of an activity can immediately alter the corresponding need intensity and its evolution trajectory. In this study, we incorporate dynamic processes and use LLMs to predict needs changes and the subsequent Need Layer to be fulfilled.

3 Implementation of DSG

We implemented an interface in Unity that automatically converts 3D scenes into DSG structures, with the visualization results shown in Figure 1. Furthermore, Figure 2 illustrates the relevant functional interfaces we defined for the DSG. The specific functionalities include the following three aspects:

Construction and Management of DSG. We designed the basic structure of the DSG (Dynamic Scene Graph), which includes three types of nodes—Room Node, Place Node, and Object Node, and

Table 2: Wilcoxon Signed-Rank Test with Bonferroni correction in Behavior Rationality with Ours ($M = 4.36, SD = 0.63$) at the correlated significance level of $\alpha = 0.007$

Method	M	SD	W	p	r
Sandbox	3.71	0.99	0	0.0240	0
W/O Time	2.21	0.89	0	0.0001	0
W/O Event	3.00	1.24	7.00	0.0063	1.87
W/O Need	2.36	0.92	2.00	0.0004	0.53
W/O PA	3.50	0.85	4.00	0.0130	1.07
W/O 3D	2.00	0.96	0	0.0012	0

two types of edges—Containment Edge and Traversability Edge. In the Unity Editor, we implemented the functionality to automatically generate the DSG structure from a given 3D scene. This functionality also incorporates visualization and interaction support, allowing users to add, modify, and delete nodes and edges, thus enabling modification and augmentation of the initially generated DSG.

Additionally, we developed functions within the **DSGManager** for updating object positions and dynamically modifying containment edges. When an object's position changes, the corresponding edge information in the DSG is updated accordingly. This allows the scene-related information to be refreshed in the activity's **Effects** after a specific activity is completed.

Natural Language Generation for SceneDescription. Building on the generation and management of the DSG, we developed a feature to generate natural language descriptions of scenes based on DSG information. This functionality utilizes predefined language templates to convert the relationships between Rooms, Places, and Objects into coherent scene descriptions. The output is formatted as a JSON file, facilitating Large Language Models (LLMs) in understanding the structural information of the scene.

Pathfinding and Route Calculation Based on the DSG Structure. To enable pathfinding from a character's position to a target object, we integrated Unity's NavMesh system with the scene's DSG node information to compute navigation paths and distances. The calculated path information is incorporated into the **ObjectInfo**, which stores the object's name and the corresponding path distance. This allows efficient navigation queries and distance calculations within the scene.

4 Detailed Data Supplement in User Study

In this section, we will show the detailed statistical results and visualize the detailed behavioral sequence results of the 14 participants from the User Study, along with each participant's Big Five Personality scores and their provided Attributes. According to the experimental requirements of our institute, we conduct relevant data collection and user study. Furthermore, all data are collected with prior informed consent, and all results are anonymized and presented with the explicit consent of the participants who contribute to the behavioral sequence results and the collection of behavior data.

The detailed statistical results of the Wilcoxon Signed-Rank Test with Bonferroni correction in Behavior Rationality and Personality Alignment are shown in Table 2 and Table 3.

Visualization Results of Participant 1 - Participant 14, as shown in Figure 3 - Figure 16. Some of the results contain blank segments, which indicate that no behavioral activities were planned during that period of time.

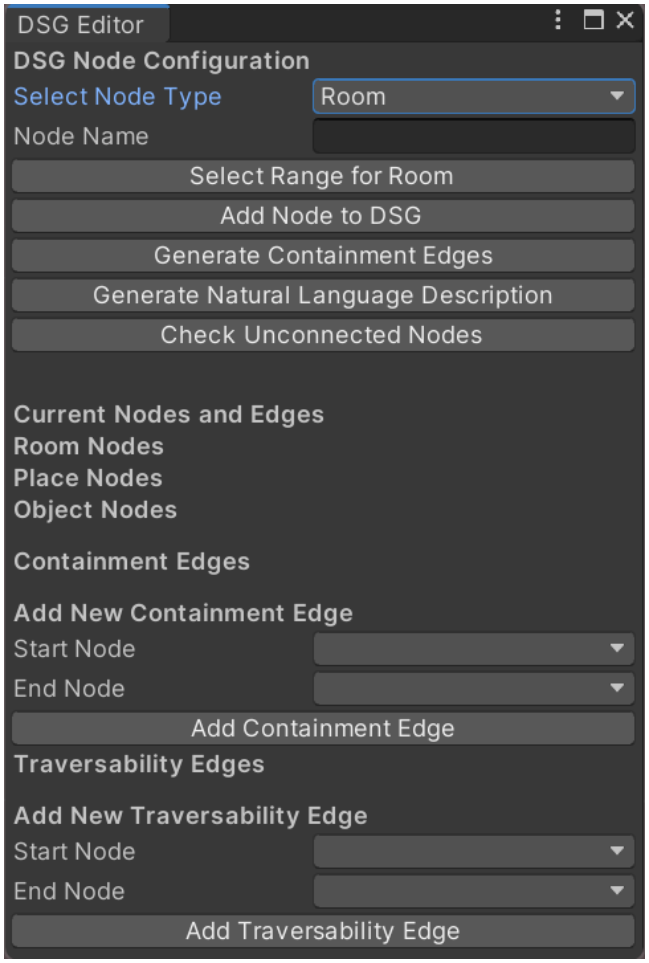

Figure 2: The display of the **DSG Interface** implemented in Unity within the Unity Editor

Table 3: Wilcoxon Signed-Rank Test with Bonferroni correction in Personality Alignment with Ours ($M = 3.64, SD = 0.93$) at the correlated significance level of $\alpha = 0.007$

Method	M	SD	W	p	r
Sandbox	3.21	1.05	20.00	0.2180	5.35
W/O Time	1.93	1.14	0	0.0020	0
W/O Event	2.57	1.28	13.50	0.0402	3.61
W/O Need	2.86	1.41	12.50	0.0610	3.34
W/O PA	2.14	0.94	0	0.0018	0
W/O 3D	2.86	0.86	12.50	0.0610	3.34

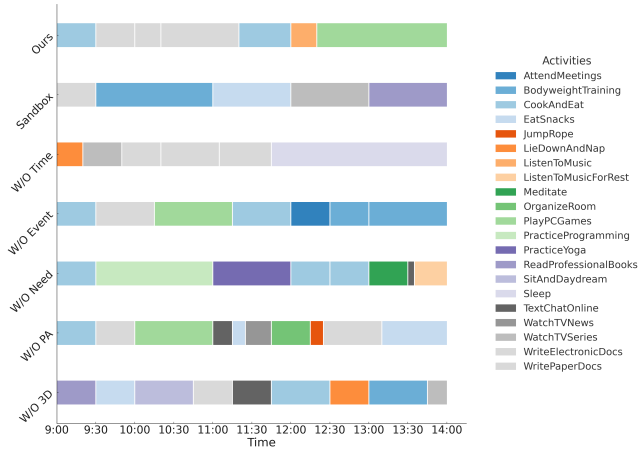

Figure 3: The participant1's generated behavior sequence of 7 conditions, whose Big-Five personality scores is O-54 C-75 E-46 A-46 N-44 and Attributes is "Male, 22 years old, 170 cm tall, weighing 60 kg, currently a graduate student. His highest educational qualification is a bachelor's degree. His hobbies include home workouts and singing, and he enjoys playing games on PC and phone." visualized by state bar.

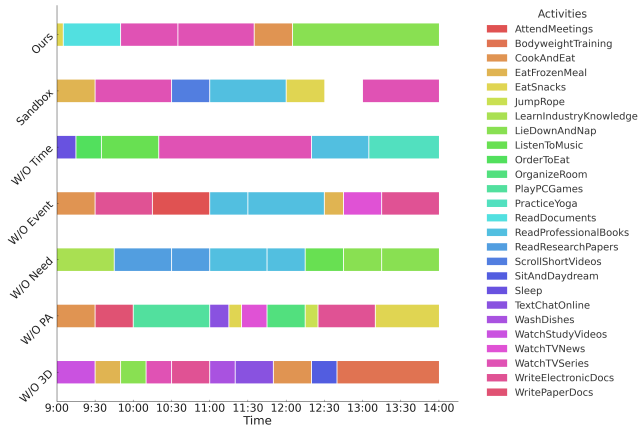

Figure 4: The participant2's generated behavior sequence of 7 conditions, whose Big-Five personality scores is O-75 C-67 E-23 A-75 N-56 and Attributes is "Female, 33 years old, 160 cm tall, weighing 49 kg, currently a teacher with a bachelor's degree. She enjoys playing badminton, watching TV series and variety shows, and taking long naps.", visualized by state bar.

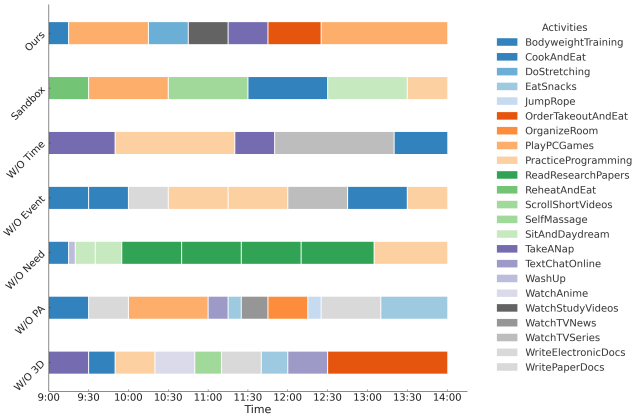

Figure 5: The participant3's generated behavior sequence of 7 conditions, whose Big-Five personality scores is O-69 C-38 E-75 A-58 N-17 and Attributes is "Male, 24 years old, 170 cm tall, weighing 90 kg, currently a student with a bachelor's degree. His hobbies include playing video games, and his unique habit at home is lying down.", visualized by state bar.

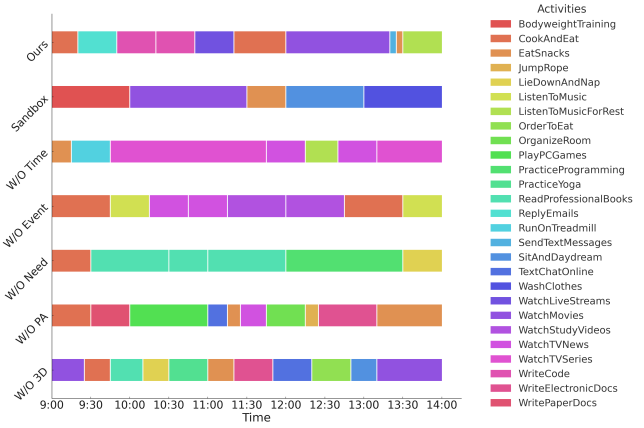

Figure 6: The participant4's generated behavior sequence of 7 conditions, whose Big-Five personality scores is O-65 C-85 E-54 A-58 N-40 and Attributes is "Female, 22 years old, 180 cm tall, weighing 58 kg, currently a student with a bachelor's degree. Her hobbies include watching movies and fitness.", visualized by state bar.

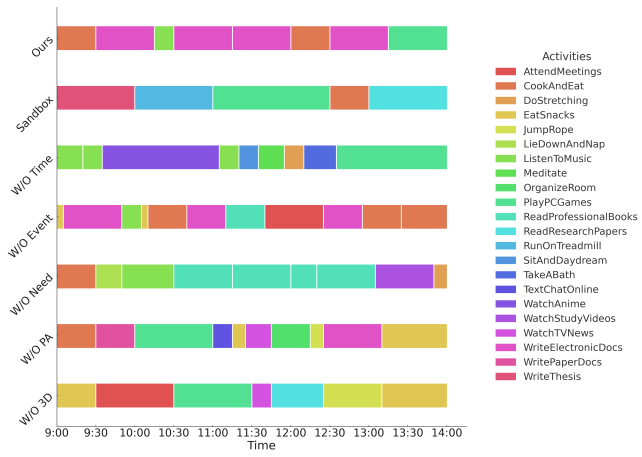

Figure 7: The participant5's generated behavior sequence of 7 conditions, whose Big-Five personality scores is O-56 C-73 E-77 A-73 N-46 and Attributes is "Female, 28 years old, 160 cm tall, weighing 53 kg, currently a PhD student with a bachelor's degree. Her hobbies include playing video games and fitness, and her unique habits at home include playing video games and watching anime.", visualized by state bar.

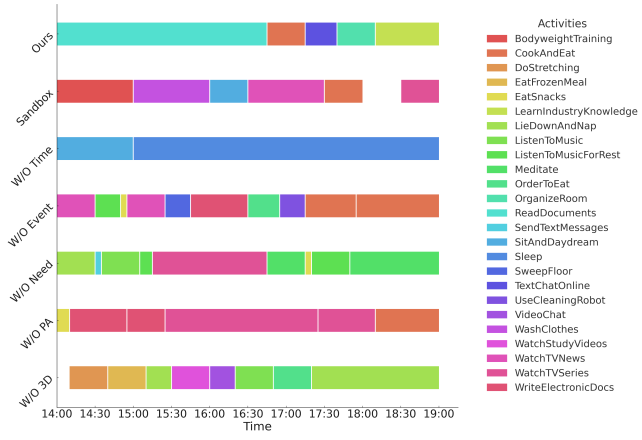

Figure 8: The participant6's generated behavior sequence of 7 conditions, whose Big-Five personality scores is O-62 C-79 E-52 A-62 N-44 and Attributes is "Male, 40 years old, 179 cm tall, weighing 75 kg, currently working as a finance professional. His highest educational qualification is a bachelor's degree. His hobbies include playing tennis, and he enjoys cleaning and organizing his home during his free time.", visualized by state bar.

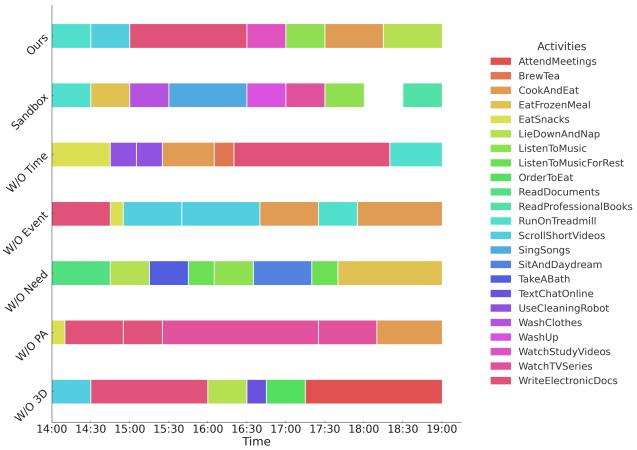

Figure 9: The participant7's generated behavior sequence of 7 conditions, whose Big-Five personality scores is O-58 C-73 E-44 A-77 N-46 and Attributes is "Female, 31 years old, 170 cm tall, weighing 65 kg, currently working as a civil servant. Her highest educational qualification is a bachelor's degree. At home, she enjoys watching short videos, has a habit of working out with equipment, likes playing the guitar and singing, and enjoys cooking for herself.", visualized by state bar.

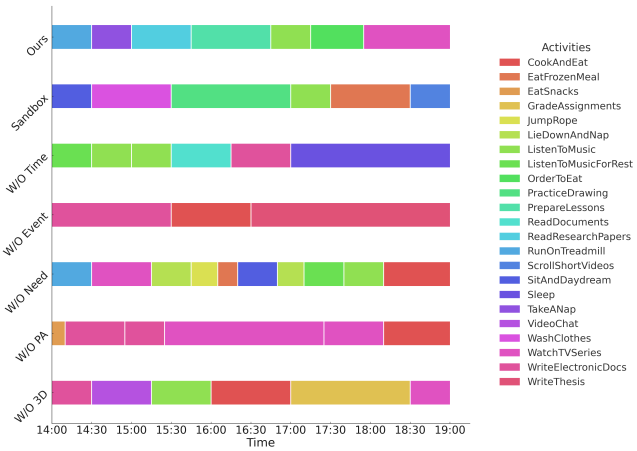

Figure 10: The participant8's generated behavior sequence of 7 conditions, whose Big-Five personality scores is O-79 C-65 E-27 A-77 N-48 and Attributes is "Male, 29 years old, 170 cm tall, weighing 69 kg, currently working as a university teacher. His highest educational qualification is a Ph.D. His hobbies include music, fitness, calligraphy, and hiking. At home, he has a special habit of enjoying sleeping in, reading books, and watching TV shows.", visualized by state bar.

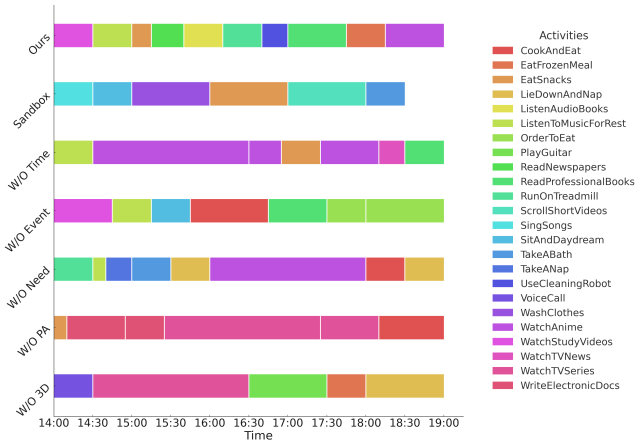

Figure 11: The participant9's generated behavior sequence of 7 conditions, whose Big-Five personality scores is O-81 C-42 E-27 A-46 N-71 and Attributes is "Female, 23 years old, 160 cm tall, weighing 45 kg, currently an undergraduate student with a highest educational qualification of high school graduation. Her hobbies include photography and singing. At home, she has a special habit of lying in bed for extended periods, enjoying watching anime and playing video games.", visualized by state bar.

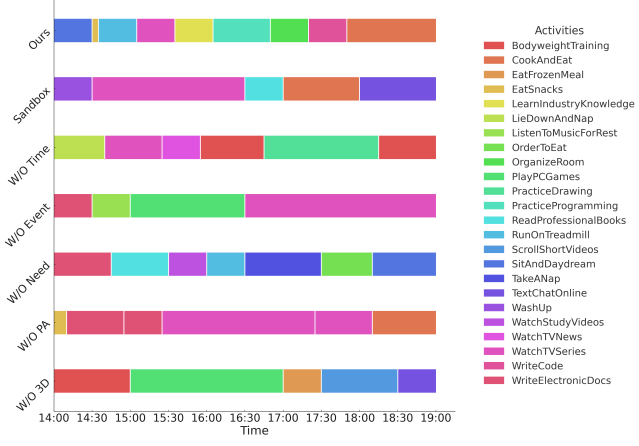

Figure 12: The participant10's generated behavior sequence of 7 conditions, whose Big-Five personality scores is O-46 C-60 E-46 A-62 N-29 and Attributes is "Male, 14 years old, 171 cm tall, weighing 58 kg, currently a junior high student. His hobbies include playing table tennis. At home, he occasionally engages in bodyweight exercises and aerobic workouts. He also enjoys watching short videos and playing computer games.", visualized by state bar.

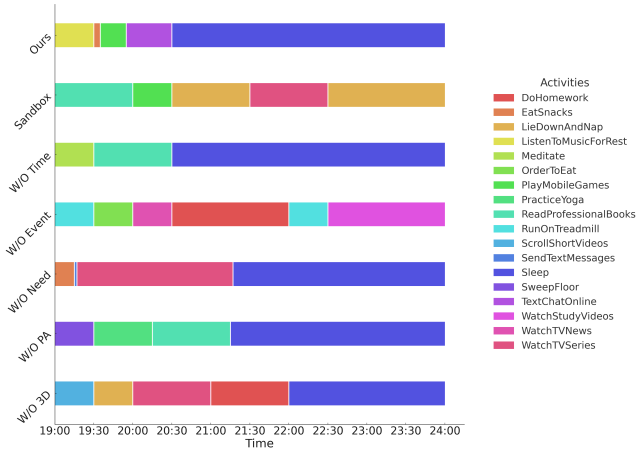

Figure 13: The participant11's generated behavior sequence of 7 conditions, whose Big-Five personality scores is O-54 C-77 E-44 A-77 N-29 and Attributes is "Male, 43 years old, 174 cm tall, weighing 87 kg, currently a business manager. His hobbies include playing badminton. At home, he enjoys sleeping, watching short videos on his phone, watching funny videos on his computer, and playing mobile games.", visualized by state bar.

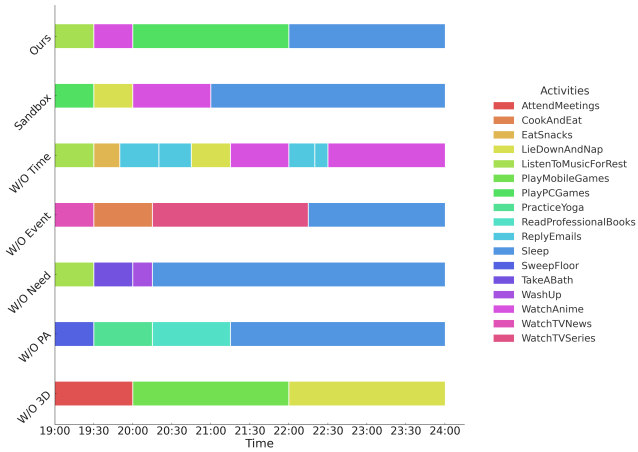

Figure 14: The participant12's generated behavior sequence of 7 conditions, whose Big-Five personality scores is O-65 C-77 E-52 A-83 N-38 and Attributes is "Female, 37 years old, 178 cm tall, weighing 72 kg, working as an IT technician with a bachelor's degree. Her hobbies include watching anime and playing video games.", visualized by state bar.

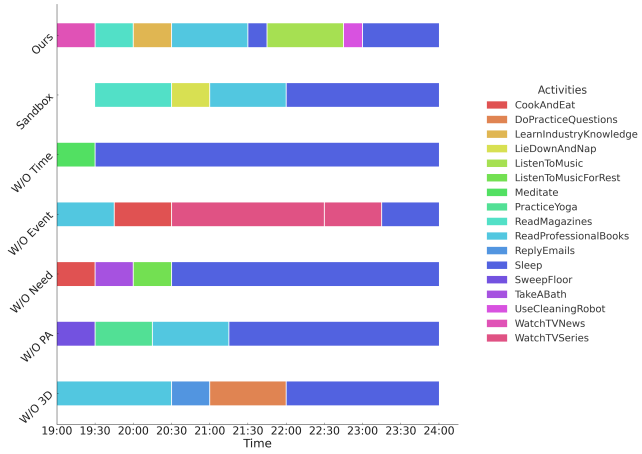

Figure 15: The participant13's generated behavior sequence of 7 conditions, whose Big-Five personality scores is O-92 C-92 E-79 A-75 N-21 and Attributes is "Female, 55 years old, 165 cm tall, weighing 55 kg, as a pre-diplomat with a master's degree. Her hobbies include reading, and she particularly enjoys reading various literary and professional books in print.", visualized by state bar.

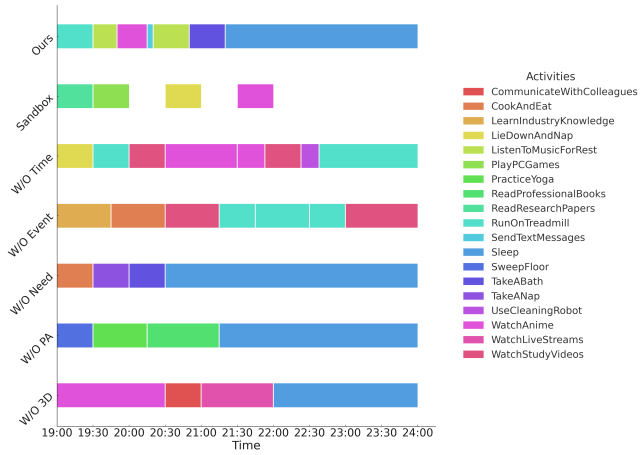

Figure 16: The participant14's generated behavior sequence of 7 conditions, whose Big-Five personality scores is O-73 C-60 E-60 A-67 N-52 and Attributes is "Male, 26 years old, 176 cm tall, weighing 93 kg, currently a medical graduate student with a bachelor's degree. His hobbies include fitness, watching Pokémon-related anime, and playing Pokémon games.", visualized by state bar.