

# Cyber-Syndrome: Concept, Theoretical Characterization, and Control Mechanism

Feifei Shi, Huansheng Ning\*, Liming Chen, and Sahraoui Dhelim

**Abstract:** The prevalence of social media and mobile computing has led to intensive user engagement in the emergent Cyber-Physical-Social-Thinking (CPST) space. However, the easy access, the lack of governance, and excessive use has generated a raft of new behaviors within CPST, which affects users' physical, social, and mental states. In this paper, we conceive the Cyber-Syndrome concept to denote the collection of cyber disorders due to excessive or problematic Cyberspace interactions based on CPST theories. Then we characterize the Cyber-Syndrome concept in terms of Maslow's theory of Needs, from which we establish an in-depth theoretical understanding of Cyber-Syndrome from its etiology, formation, symptoms, and manifestations. Finally, we propose an entropy-based Cyber-Syndrome control mechanism for its computation and management. The goal of this study is to give new insights into this rising phenomenon and offer guidance for further research and development.

**Key words:** Cyber-Syndrome; cyber-physical systems; Cyber-Physical-Social-Thinking (CPST) space; Maslow's Hierarchy of Needs; entropy

## 1 Introduction

The overwhelming advances in information and communication technologies have created a digital world, bringing significant benefits to our daily lives and industrial manufacturing<sup>[1]</sup>. The digital world, also named as Cyberspace, has become "normalized" as a new kind of living space for humans. Cyberspace is regarded as an Internet metaphor referring to people, objects, and things being connected and communicating on the Internet<sup>[2]</sup>. Businesses and

corporations are also gradually joining Cyberspace, eyeing the convenience, vitality, and ease of reaching almost 5 billion active Internet users all over the world<sup>[3]</sup>. It is no longer just a tool for entertainment, but a necessity for work and daily routines<sup>[4]</sup>. However, the overwhelming penetration makes people spend more time in Cyberspace and has led to a series of severe effects on users' physiological and psychological health<sup>[5, 6]</sup>.

Many scholars have paid attention to the health and disease in Cyberspace and put forward various opinions. For example, in the 1990s, Young et al.<sup>[7]</sup> proposed the concept of cyber disorders which mainly focused on mental health concern during the interaction with the Internet. Gregory<sup>[8]</sup> specified the concept of Internet addiction disorder and defined it as a series of symptoms due to the problematic use of the Internet, accompanied by withdrawal effects. It is one of the most studied topics so far, although still not recognized as a formal disorder in the diagnostic and statistical manual of mental disorders. Researchers in various

- 
- Feifei Shi and Huansheng Ning are with School of Computer and Communication Engineering, University of Science and Technology Beijing, Beijing 100083, China. E-mail: shifeifeiustb@163.com; ninghuansheng@ustb.edu.cn.
  - Liming Chen is with Faculty of Computing, Ulster University, Newtownabbey, BT37 0QB, UK.
  - Sahraoui Dhelim is with School of Computer Science, University College Dublin, Dublin, D04 V1W8, Ireland.

\* To whom correspondence should be addressed.

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fields are making contributions to these studies from different perspectives. For example, Lozano-Blasco et al.<sup>[9]</sup> analyzed the influential factors of Internet addiction in adults from social and psychological aspects, including age, sex, geographical factors, etc. Sun et al.<sup>[10]</sup> attempted to establish a deep learning method of Internet addiction diagnosis based on Electroencephalogram (EEG) signals and provided a quantitative analysis with advanced technologies. They tried to figure out the mechanism of Internet addiction from a scientific and comprehensive perspective so that it could be identified, diagnosed, and treated in time. In addition to Internet addiction disorder, there are also concepts such as Cybersickness and Cyberchondria. The former refers to physical disorders during or after immersion into virtual spaces<sup>[11]</sup>, while the latter addresses health concerns due to information overload<sup>[12]</sup>.

In our prior research on cyber health, we have established associations between Internet use and physical complaints<sup>[13]</sup>. Subsequently, we characterized the emerging phenomenon of physical, social, and mental disorders as a new type of disease which is dubbed as Cyber-Syndrome<sup>[14]</sup>. We have continued to conduct in-depth research in recent years around the concept of Cyber-Syndrome.

As we know, the Internet enables almost everything in physical, social, and thinking spaces to be connected and has largely accelerated the formation of Cyber-Physical-Social-Thinking (CPST) space<sup>[15]</sup>. Therefore, we conceive that Cyber-Syndrome will not only be a disease due to Cyberspace in general but also be more specifically closely related to the CPST space. It not only stems from unhealthy interactions with Cyberspace but also is indirectly affected by factors in the physical, social, and thinking spaces. For example, people who are dissatisfied with their living conditions in real life would resort to virtual Cyberspace, which provides possibilities for their excessive interaction with Cyberspace and may further induce Cyber-Syndrome. In addition, Cyber-Syndrome is such a complicated disease with various symptoms in different spaces, such as headache and obesity in the physical space, social isolation in the social space, and depression and anxiety disorders in the thinking space.

In this paper, we provide an overall understanding of Cyber-Syndrome, ranging from its concept, characterization, and control mechanism. Firstly, we

define the concept of Cyber-Syndrome and illustrate its connotation based on the CPST space theories. Subsequently, we analyze the etiology and formation by identifying the influential factors in each space and introduce the cyber-enabled symptoms and manifestations. Following that, an entropy-based control mechanism for Cyber-Syndrome is proposed, which may provide potential guidance for practical intervention.

The remainder of this paper is organized as follows. Section 2 presents the concept and connotation of Cyber-Syndrome based on the CPST space theories. Section 3 characterizes the influential factors of Cyber-Syndrome upon which the etiology and formation of Cyber-Syndrome are described in detail. Section 4 elaborates on the cyber-enabled symptoms and manifestations of Cyber-Syndrome mapping into the CPST space, respectively. Section 5 describes an entropy-based control mechanism for Cyber-Syndrome followed by conclusions and discussions of future directions in Section 6.

## 2 Definition and Connotation of Cyber-Syndrome

The concept of Cyber-Syndrome with the etymology of “Cyber” and “Syndrome” was first discussed in Ref. [14]. The prefix “Cyber” is a Greek term that originally refers to networks of computers. Nowadays it is commonly used to express scenarios with reference to Cyberspace. For example, many researchers mention that we are living in a “cyber age”. The “Syndrome” refers to sets of medical symptoms and signs that are associated with one or more diseases or disorders. Therefore, in terms of etymology, Cyber-Syndrome should be a complicated disease user may suffer due to excessive interaction with Cyberspace.

As we all know, Cyberspace provides users with a virtual living world parallel to the real world. At the same time, it also drives the development of traditional physical, social, and thinking spaces, and forms the convergence of CPST space. Inspired by the theories of CPST space, we argue that Cyber-Syndrome cannot be defined and explained only in Cyberspace but should be comprehensively understood from the broader perspective of CPST space, the new totality of living space for humans. In this section, we give an introduction to the theories of CPST space first and then analyze the definition and connotation of Cyber-

Syndrome.

## 2.1 Theory of CPST space

In 2015, Ning and Liu<sup>[15]</sup> first proposed the concept of CPST space, which describes a general blueprint of spaces where humans live. Figure 1 has shown the physical, social, thinking, and cyber spaces, respectively.

The physical space is composed of humans, animals, plants, buildings, atmosphere, and other environmental elements. It is regarded as the primary living space for humans and provides fundamental conditions for human survival. The social space, as name suggests, is formed by the relationships between humans. It may be originally established upon geographical locations, blood lineage, social reasons, and other relations. Nowadays, humans are tightly connected with each other through various electronic devices and online social media. The social communications could proceed smoothly even if the two sides are thousands of miles apart. Different from other living spaces, humans in the social space are playing much more central roles under a new paradigm of Internet of People (IoP)<sup>[16]</sup>. They strived to establish good relationships with others to gain love, respect, and recognition and to maintain a sense of value and belonging.

Thinking space is an individual's private and intelligent space driven by the wonderful brains. Different from other species, humans have independent thinking space, full of different ideas and creativity, which enables them to be full of wisdom when dealing with the external events. Cyberspace, obviously, is the virtual world brought by the Internet, where humans could carry on various activities such as entertainment, socialization, commerce, study, and work. In recent years, there are more and more users spending time in Cyberspace passively or actively. Excessive interaction

with Cyberspace is regarded as the most direct cause of Cyber-Syndrome.

## 2.2 Definition and connotation of Cyber-Syndrome based on CPST space theories

To the best of our knowledge, Cyber-Syndrome is caused by the excessive interaction with Cyberspace directly, while the indirect influences from physical, social, and thinking spaces cannot be neglected. For example, when people are unable to meet their self actualization needs in real life, they may choose to avoid potential risks that may exist in the real world by immersing themselves in Cyberspace.

Hence, we redefine Cyber-Syndrome as a complicated disease that is mainly influenced by Cyberspace but cannot be separated from physical, social, and thinking spaces. In a sense, the Cyber-Syndrome expounds a more formal and much broader connotation for diseases in Cyberspace, which provides an overall understanding for relevant research communities.

In order to clearly explain the definition and connotation of Cyber-Syndrome in light of CPST, we present and compare similar and relevant disorders with reference to the Cyberspace.

### 2.2.1 Internet addiction disorder

Internet addiction disorder, the most familiar concept around cyber health, emphasizes the psychological dependence on the Internet or electronic devices. It mainly stems from problematic or compulsive Internet use, in which patients suffer from withdrawal symptoms<sup>[17-19]</sup>. Although Internet addiction may bring physical and social complications, the most obvious symptom is the psychological addiction to the Internet, making it difficult to control the amount of time spent online.

### 2.2.2 Cyber disorder

Cyber disorders refer to the influence of Cyberspace on

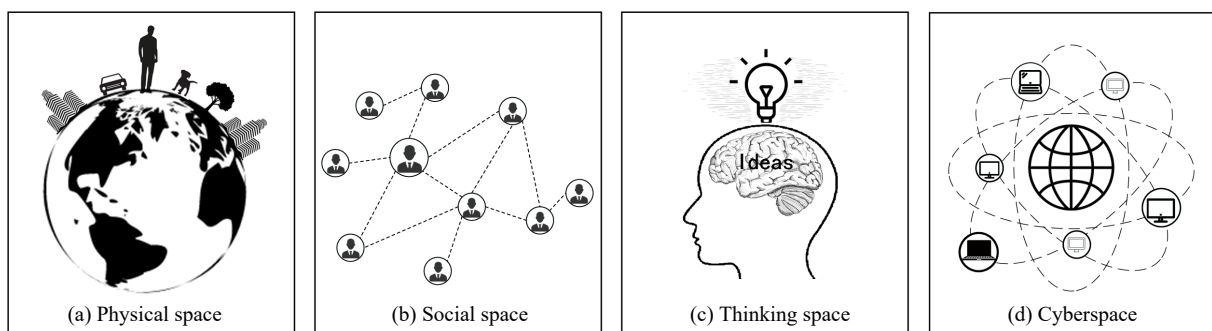


Fig. 1 Cyber-Physical-Social-Thinking space<sup>[15]</sup>.

mental health, with social, psychological, and occupational impairment<sup>[7]</sup>. In 2015, Thanasekaran and Chala<sup>[20]</sup> introduced 5 types of cyber disorders, namely cyberbullying, cyber sexual addiction, cyber-relationship addiction, computer addiction, and Internet addiction. Compared with Internet addiction disorder, cyber disorders are much broader and could cover the symptoms and signs brought by Internet addiction disorder to some extent.

### 2.2.3 Cybersickness

Cybersickness is a kind of motion sickness that results from exposure to Cyberspace, especially in virtual environments<sup>[11, 21]</sup>. Similar to motion sickness, people with Cybersickness are sometimes over-stimulated by cyber technologies or cyber equipment, which causes symptoms such as confusion, nausea, headache, dizziness, and sweating. For example, if users scroll down the screen quickly, they may feel dizzy to some extent. The most prevalent remedy is to stop long-time cyber exposure and take rest to alleviate the sickness.

### 2.2.4 Cyberchondria

Cyberchondria refers to the unfounded escalation of health concerns when searching for information online<sup>[12, 22]</sup>. Different from the diseases mentioned above, Cyberchondria represents the impact of cyber information overload, especially when searching for health-related information. Humans with Cyberchondria may experience slight or heavy anxiety when facing complicated information or hints about their health in Cyberspace.

Table 1 has compared the Cyber-Syndrome and other similar concepts. In terms of the definition, most existing related concepts focus on specific perspectives, such as the psychological dependence, the physical discomforts, etc. In contrast, the definition of Cyber-Syndrome is much broader and covers more content. It not only stems from excessive exposure to Cyberspace but also is influenced by factors in physical, social, and thinking spaces. Additionally, from the perspective of symptoms, Cyber-Syndrome includes a series of symptoms in Cyberspace and cyber-enabled physical, social, and thinking spaces, which will be illustrated in detail in the following sections.

## 3 Etiology and Formation of Cyber-Syndrome

As mentioned above, the Cyber-Syndrome is a complicated disease with sets of disorders related to the living spaces of humans. Therefore, its etiology and formation cannot be easily explained only by excessive or problematic Internet use. It is caused by many factors and has complex etiology and pathological mechanisms. In this section, we explore a new method to characterize the etiology of Cyber-Syndrome according to CPST space and the theory of Maslow's Hierarchy of Needs, aiming to illustrate the formation of Cyber-Syndrome from a theoretical point of view, without involving any professional pathological analysis.

**Table 1 Some typical concepts around health in Cyberspace.**

Name	Definition	Symptom	Reference
Internet addiction disorder	Internet addiction disorder emphasizes the psychological disorders due to excessive Internet use and is accompanied by withdrawal effects after cessation of Internet use.	Psychological dependence and obvious signs in emotion and physical bodies, like depression, anxiety, loneliness, backache, and insomnia.	[17–19]
Cyber disorder	Cyber disorder refers to the mental health concern associated with significant social, psychological, and occupational impairments.	Loss of self-esteem, self-confidence, and sense of security; types of cyber sexual addiction, cyberbullying, cyber-relationship addiction, computer addiction, and Internet addiction.	[7, 20]
Cybersickness	Cybersickness represents the negative feelings users suffer during or after immersion into virtual reality. It concentrates more on physical disorders.	Nausea, headache, dizziness, and sweating.	[11, 21, 23]
Cyberchondria	Cyberchondria represents the unfounded escalation of health concerns during web searches, mainly manifested in psychological and mental problems.	Overwhelming anxiety and fear, unexpected investment of time, as well as expensive engagements with healthcare professionals.	[12, 22]
Cyber-Syndrome	Cyber-Syndrome includes the physical, social, and mental disorders due to excessive Cyberspace interaction.	Tactile sensation, radiation exposure, behavior disorders, mood disorders, social anxiety, and social hostility.	[14]

As we know, the CPST space provides humans with various conditions to satisfy their living requirements. For example, humans in physical space need to pursue food, water, warmth, etc., to keep a basic living environment. Humans in social space need to establish relationships with others to obtain a sense of social belonging. In other words, humans' behavior in CPST space is closely related to satisfying their needs. The famous Maslow's Hierarchy of Needs describes humans' needs at different levels, including physiological needs, safety needs, love and belonging needs, esteem needs, and self-actualization<sup>[24]</sup>. According to the theories, physiological needs and safety needs are basic ones, which are the primary requirements needed to be satisfied for humans. Motivations like love and belonging, esteem, and self-actualization are more advanced, and only when the basic requirements are satisfied, humans would like to pursue these higher-level needs to realize self-affirmation and self-worth.

We notice that Maslow's Hierarchy of Needs has something to do with the traditional Physical-Social-Thinking (PST) spaces. For example, the primary physiological needs of food, water, warmth, etc., are dominant in the physical space. Safety needs emphasize more on the safety and stability of daily living. Compared to physiological needs, safety needs could be reflected in both physical and social spaces. For instance, health and life safety needs are more likely to be in the physical space, while the needs for the stability of employment and family relations are more dominant in the social space. Additionally, the love and belonging needs refer to the requirements of

friendship, love, and the sense of belonging. Hence, it is much more consistent with the requirements in the social space, where humans hope to build friendly and close relationships with others. Esteem needs are regarded as higher-level needs and include self-esteem as well as the need to be respected by others. They are manifested as the desire to gain strength, achievement, and independence and to be appreciated and highly praised by others. Hence, for the desire for respect and recognition from others, they tend to belong to the requirements in the social space, while the ultimate realization of self-awareness and self-esteem tends to be more inclined toward the thinking space. As for the upper levels of self-actualization needs, they are motivations of self-fulfillment and prevalingly correspond to the requirements in the thinking space.

The mapping relations have been depicted in Fig. 2. It can be seen that the most dominant mapping relationships between different levels of needs and spaces have been illustrated. The Maslow's Hierarchy of Needs mainly describes the motivations of humans, and the PST spaces are regarded as humans' basic living spaces. To be noted, there does exist some overlapping between the different levels of needs and living spaces. What we depict here emphasizes more on the most dominant and distinct relationships in order for a clearer introduction to the etiology and formation of Cyber-Syndrome.

As mentioned above, Cyber-Syndrome not only results from unhealthy interactions with Cyberspace but also is affected by factors in PST spaces. According to the mapping analysis between different levels of needs and spaces, Fig. 3 interprets the

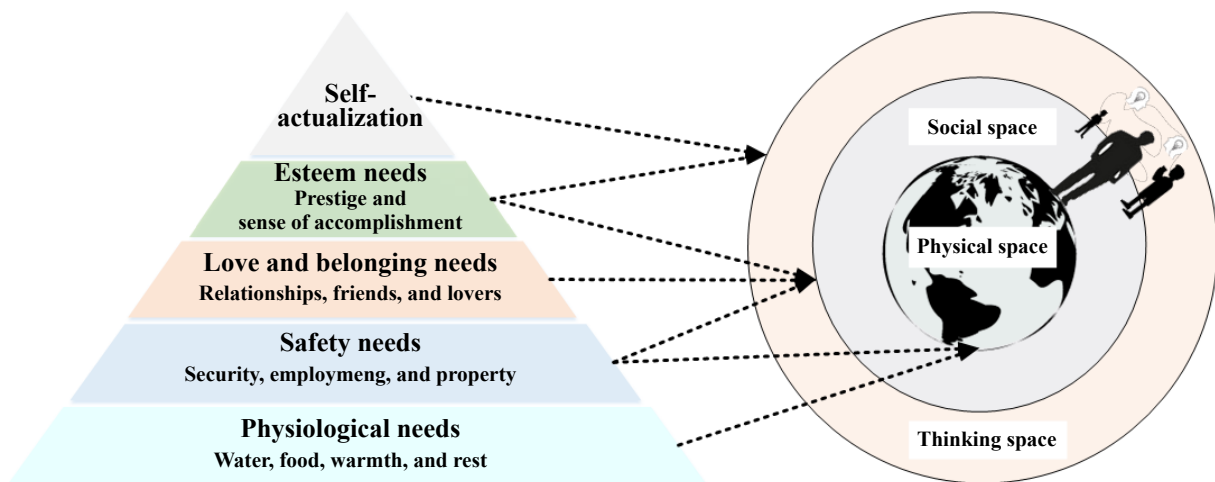


Fig. 2 Five-tier Maslow's Hierarchy of Needs corresponding to the PST space<sup>[24]</sup>.

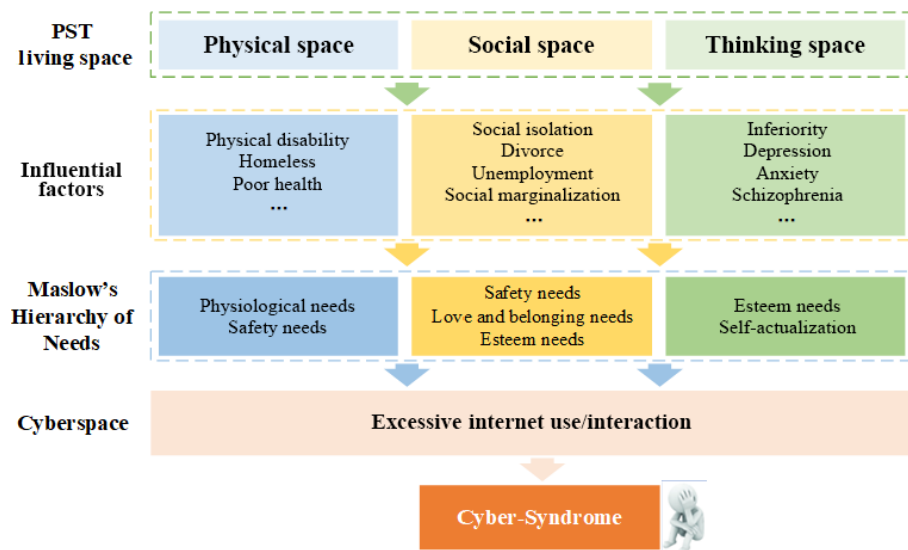


Fig. 3 Etiology and formation of Cyber-Syndrome in terms of CPST space and Maslow's Hierarchy of Needs.

etiology and formation of Cyber-Syndrome by analyzing influential factors in each space.

In the physical space, humans need to satisfy basic requirements such as the physiological needs of water, food, and warmth for primary living, the safety needs of health, etc. These motivations encourage humans to work hard to ensure the primary living environment. However, people may suffer from physical disability, poor health, homelessness, and other painful experience and fail to meet the expectations in the physical space. The frustrations in real life may lead people to turn their attention to Cyberspace, resulting in excessive Internet use. There are some cases in which people throw themselves into virtual Cyberspace due to disappointments in the physical space. For example, Martínez<sup>[25]</sup> made an investigation among people with and without disabilities, and explored whether there are relationships between abusive Internet use and disabilities. The results have suggested that people with motor disabilities have more chances to be addicted to the virtual space.

In the social space, humans desire to attain love and a sense of belonging. On the basis of physiological and life safety needs, people tend to establish a safe environment with good jobs and stable relationships with others. They aim to acquire love, respect, and a sense of belonging, including affiliation, trust, friendship, intimacy, affection, etc. Nevertheless, unemployment, social isolation, deception, divorce, and social marginalization may be obstacles to achieving love and belonging. People who are

dissatisfied with their social status and relationships are more likely to have evasive emotions and throw themselves into the Internet and Cyberspace. For example, Rumpf et al.<sup>[26]</sup> made an investigation of the occurrence of Internet addiction in a general population sample and found that the unemployment background was extremely related to Internet addiction. In 2009, Tsai et al.<sup>[27]</sup> made a survey of risk factors of Internet addiction among university freshmen and discovered that the poorer social support had higher possibilities of Internet excessive interaction.

In the thinking space, most human beings are born to expect attention, recognition, and prestige from others, and achieve self-actualization. This is largely due to their superiority in thoughts, ideas, and creativity. However, life may not be so pleasant, and humans who are confronted with various challenges would lose confidence in themselves. They may feel embarrassed and troubled by mental illnesses such as depression, anxiety, and schizophrenia. At this stage, humans with mental disorders may feel more comfortable when addicted to Cyberspace and would like to spend more time in the virtual world. For instance, Ni et al.<sup>[28]</sup> once demonstrated a survey among freshmen college students, and came to the conclusion that there was a strong association between Internet addiction and depression, anxiety, etc.

To demonstrate the association between Cyber-Syndrome and influencing factors in different living spaces, we conduct an investigation among college students with questionnaire. The questionnaire is

designed based on the Adolescent Pathological Internet Use Scale (APIUS) and contains questions about influential factors in various living spaces<sup>[29]</sup>. For example, in physical space, questions of age, sex, and family income are designed, and in social space, questions with reference to family and roommate relationships are investigated. In thinking space, the personality of subjects and their understanding of themselves are examined. In Cyberspace, the time subjects spend on the Internet are recorded. In addition, the questionnaire also contains 33 items to determine the subjects' dependence on Cyberspace and 20 items to estimate the severity of Cyber-Syndrome. Based on the previous definition of Cyber-Syndrome, the excessive or pathological interaction with Cyberspace is the direct cause of Cyber-Syndrome, and the possible influencing factors in PST space are mainly classified as indirect factors. For all measurements such as the dependence on Cyberspace and the severity of Cyber-Syndrome, they are represented by the mean value  $\pm$  the standard deviation. The univariate analysis is adopted to demonstrate the inter-group comparison, and  $p$  value is used as the difference indicator. When  $p$  value is less than 0.05, it indicates a significant difference between the two groups. When  $p$  value is less than 0.01, it indicates an extremely significant difference between the two groups.

A total of 138 valid questionnaires are ultimately collected. As shown in Table 2, the association analysis between some potential indirect factors in PST space and the dependence on the Cyberspace is illustrated. For example, for participants between different grades, the dependence on the Cyberspace shows an extremely significant difference with a  $p$  value less than 0.01. Among all grades, the general dependence of sophomore is more obvious. During the junior and senior stage, with the advent of graduation, further education, and employment, the dependence on the Cyberspace is not as severe as before. For differences between male and female, the investigation shows that the Cyberspace dependence of male is more distinct than that of female. For family status, participants from the nuclear family have stronger ability to deal with Cyberspace dependence compared with other types. It proves that healthy and safe family environment does have positive impacts on the dependence of the Cyberspace. The influence of personality on Cyberspace dependence is also explored, and the

results show that there are extremely distinct differences between various types of personality, with a  $p$  value of about 0.006 17. Additionally, other factors such as the relationship with roommates, the relationships with parents, and the degree of satisfaction of campus life are also investigated. The results have proved that the influential factors in PST space do have certain associations with the dependence on the Cyberspace.

Moreover, we also conduct the analysis between the time spent in the Cyberspace per day and the severity of Cyber-Syndrome. As can be seen in Fig. 4, according to the time spent in the Cyberspace per day, the participants are divided into 3 groups, namely less than 2 h ( $28.2857 \pm 12.3315$ ), 2–5 h ( $40.1731 \pm 18.212$ ), and more than 5 h ( $48.3333 \pm 16.5988$ ). It can be seen that as the time spent in Cyberspace increases, the score of the Cyber-Syndrome becomes higher. Pairwise comparison between groups has revealed statistically significant differences ( $p < 0.05$ ), and the differences between the group of less than 2 h and the group of more than 5 h are extremely significant ( $p < 0.01$ ).

To sum up, Cyber-Syndrome is a complicated disease jointly impacted by factors in CPST space. Humans who fail to satisfy Maslow's Hierarchy of Needs in real life are more likely to indulge into Cyberspace and are easy to get sick with Cyber-Syndrome. The indirect influential factors in PST space may result in the excessive interaction and addiction to the Cyberspace and finally aggravate the formation of Cyber-Syndrome.

#### 4 Cyber-Enabled Symptoms of Cyber-Syndrome

In order to comprehensively understand Cyber-Syndrome, it is also important to recognize its symptoms. In this section, we create the mapping paradigm of cyber-enabled symptoms according to the CPST space by concluding key markers of Cyber-Syndrome manifestations in each space.

As can be seen in Fig. 5, we first interpret the cyber-enabled relationship between Cyberspace and traditional physical, social, and thinking spaces<sup>[1]</sup>, namely the cyber-enabled physical, social, and thinking spaces. It describes the cyberization process of PST spaces brought by the rapid evolution of Cyberspace. For example, in cyber-enabled physical space, smart

**Table 2 Relationship between some influential factors in PST space and the dependence on Cyberspace.**

Influential factor	Participants group	Number of subjects	Dependence on Cyberspace	F-score	<i>p</i>
Grade	Freshman	14	101.3571 ± 41.8101	4.9236	0.000 98**
	Sophomore	17	136.7059 ± 26.1798		
	Junior	34	107.8235 ± 36.8051		
	Senior	64	94.9219 ± 33.0054		
	Postgraduate	9	99.5556 ± 36.0559		
Gender	Male	50	114.0000 ± 39.7703	5.6768	0.018 57*
	Female	88	98.6364 ± 34.3743		
Family status	Nuclear family	80	99.4875 ± 36.6361	4.6621	0.011 03*
	Single-parent family	25	124.5600 ± 27.5047		
	Larger extended family	33	100.2121 ± 39.9107		
Academic record	Very poor	8	130.2500 ± 20.4363	3.0270	0.012 00*
	Poor	14	118.0000 ± 25.3438		
	Neutral	59	99.0848 ± 37.1253		
	Good	41	96.1220 ± 36.2065		
	Very good	16	118.6875 ± 43.5916		
Family income	<3000 RMB	6	123.1667 ± 23.6339	2.2424	0.067 80
	3000–5999 RMB	38	107.2632 ± 35.3719		
	6000–9999 RMB	51	108.3529 ± 36.0349		
	10 000–15 999 RMB	27	101.2963 ± 40.7844		
	>16 000 RMB	16	81.5000 ± 34.5890		
Parents relations	Poor	13	125.9231 ± 21.3521	3.5293	0.032 10*
	Neutral	30	110.0000 ± 37.3215		
	Good	95	99.4000 ± 37.5625		
Father's educational background	Primary education	11	85.1818 ± 30.976 80	5.9420	0.000 79**
	Junior secondary education	39	91.1282 ± 31.396 60		
	Senior secondary education	29	101.0690 ± 37.002 83		
	Higher education	59	117.9322 ± 37.227 57		
Satisfaction of campus	Satisfied	96	101.0313 ± 39.6000	1.9669	0.143 88
	Neutral	26	105.8462 ± 32.0184		
	Dissatisfied	16	120.5625 ± 25.4348		
Roommates relations	Harmonious	108	101.9074 ± 38.3717	1.0948	0.337 60
	Neutral	20	109.9500 ± 33.7210		
	Disharmonious	10	117.5000 ± 25.1186		
Personality	Very introvert	9	138.6667 ± 23.7540	3.7677	0.006 17**
	Introvert	42	98.6905 ± 32.1471		
	Neutral	40	109.7500 ± 35.4457		
	Extrovert	40	93.9500 ± 36.5646		
	Very extrovert	7	119.8571 ± 58.7124		

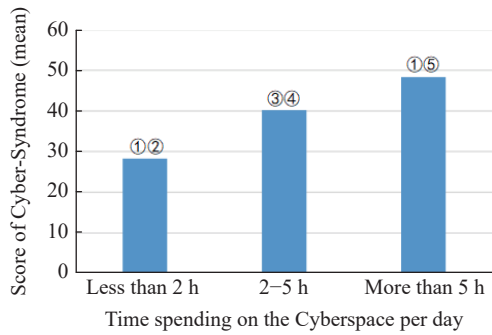
Note: \*:  $p < 0.05$  and \*\*:  $p < 0.01$ .

transportation is enabled with advanced techniques and will provide much more intelligent services. Inspired by it, we emphasize the signs of Cyber-Syndrome as cyber-enabled symptoms in each space. It means sets of symptoms that could be triggered or aggravated by

Cyberspace or cyber techniques in certain circumstances, including physical, social, and thinking disorders. Figure 5b has illustrated its cyber-enabled symptoms.

First of all, Cyber-Syndrome has the most explicit





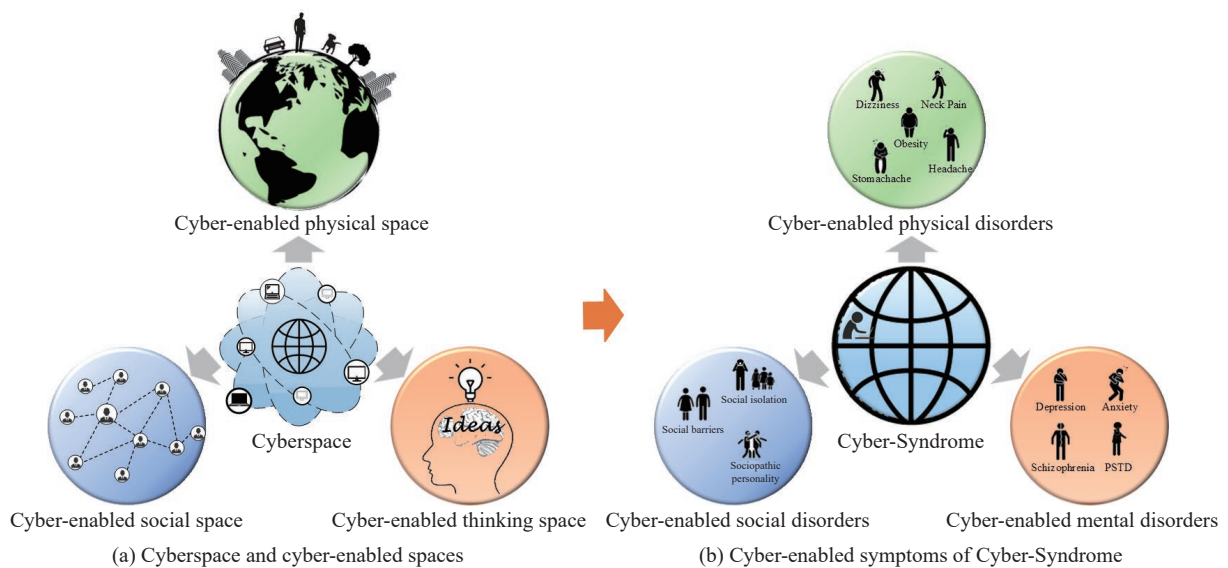
**Fig. 4 Association between the time spent in the Cyberspace and the score of the Cyber-Syndrome.** ①:  $p < 0.05$ , compared with the group of 2-5 h; ②:  $p < 0.01$ , compared with the group of more than 5 h; ③:  $p < 0.05$ , compared with the group of less than 2 h; ④:  $p < 0.05$ , compared with the group of more than 5 h; ⑤:  $p < 0.01$ , compared with the group of less than 2 h.

symptoms in Cyberspace, which refers to the unhealthy or excessive Internet interaction. Sometimes when humans suffer from severe Cyber-Syndrome, they may show obvious addictive symptoms. At this stage, people may spend more time in Cyberspace and are vulnerable to a series of risks such as cyberbullying, cybercrime, and cyber fraud. All those factors would do harm to human health, especially in the mental and psychological aspects. For example, cyberbullying depicts the detrimental effects of posting or sending personal information over digital space. It may lead victims to embarrassment and humiliation.

In addition to Cyberspace, people who get sick with Cyber-Syndrome also show different symptoms in the

cyber-enabled PST spaces. In the physical space, humans with Cyber-Syndrome may show up various physiological symptoms such as dizziness, neck pain, headache, and obesity. Most people who are addicted to Cyberspace would like to keep the same body posture for a long time, and it is easier to have impacts on the healthy states of the head, neck, fingers, back, eyes, and so forth. For example, it has been proved that the prolonged screen time has direct impacts on myopia particularly among infants, children, and adolescents<sup>[30]</sup>. In addition, problematic Internet use also triggers problems related to the duration and quality of sleep, as well as the cardiovascular systems<sup>[31]</sup>. It is worth noting that the symptoms mentioned above are also common in other diseases related to physical conditions, but unhealthy long-term Internet interaction does aggravate the symptoms to some extent.

In the social space, people with Cyber-Syndrome also present quite some cyber-enabled social symptoms. For example, most people with Cyber-Syndrome fail to satisfy love and belonging needs and may be confused with social relationships in real life. They escape from the dissatisfied environments and throw themselves into the virtual space, which in turn worsens the situations in real life. By establishing virtual relationships instead of face-to-face communications, the situation of social isolation may become severe and further prevent people to participate in various social activities. In 1998, Saito<sup>[32]</sup> published a book named *Social Withdrawal*. It introduced the



**Fig. 5 Cyber-enabled spaces and cyber-enabled symptoms of Cyber-Syndrome.**

concept of social withdrawal which usually took place when escaping from social activities for more than six months. Following it, Tateno et al.<sup>[33]</sup> found that there was an overwhelming influence between Internet addiction and social withdrawal. Besides, there are also other cyber-enabled social disorders with Cyber-Syndrome, such as social barriers and sociopathic personality. People with these social disorders are more willing to interact with Cyberspace, which would intensify the formation of Cyber-Syndrome.

Last but not least, Cyber-Syndrome also shows cyber-enabled mental symptoms in thinking space. When it comes to thinking space, people with Cyber-Syndrome are more likely to feel loneliness, depression, and anxiety. For example, Shekar and Aravantagi<sup>[34]</sup> pointed out that there was a strong relationship between overwhelming online information and anxiety. The easily available online information played a catalytic role in anxiety particularly during COVID-19. Ge et al.<sup>[35]</sup> provided systemic research around healthy rumors in COVID-19, and those who were easy to be “infected” by rumors would feel anxious and panic and some even lose the ability to think independently. More seriously, Love et al.<sup>[36]</sup> found that the addiction to the Internet was such a craving behavior that may suffer from changes in the structure of the frontal lobe of the brain, which impacted the ability of humans to filter information and make reasonable decisions<sup>[37]</sup>.

We have analyzed the cyber-enabled symptoms of Cyber-Syndrome based on different space. Although Cyber-Syndrome mainly results from excessive Internet use in Cyberspace, it also shows hints in cyber-enabled physical, social, and thinking spaces. If someone is experiencing long-term Cyberspace interaction and has presented similar symptoms discussed in this section, he or she may be confused with Cyber-Syndrome and should seek for professional help as soon as possible.

## 5 Entropy-Based Control Mechanism of Cyber-Syndrome

Cyber-Syndrome is still being regarded as a newly emerging phenomenon with little knowledge of early detection and diagnosis. In this section, we establish a control mechanism for Cyber-Syndrome based on the Entropy theories.

According to the second law of thermodynamics, the entropy measures the state of information randomness

and disorders. It is said that an enclosed system would tend to become more and more chaotic with higher entropic states if there is no external inputs. Inspired by it, Aoki<sup>[38]</sup> initially established the theories of entropy in human body, which could also be regarded as a thermodynamic system. In other words, as thermodynamic systems, human bodies are prone to develop from healthy states to sub-healthy or unhealthy states if there is no external intervention, with entropy developing towards higher states.

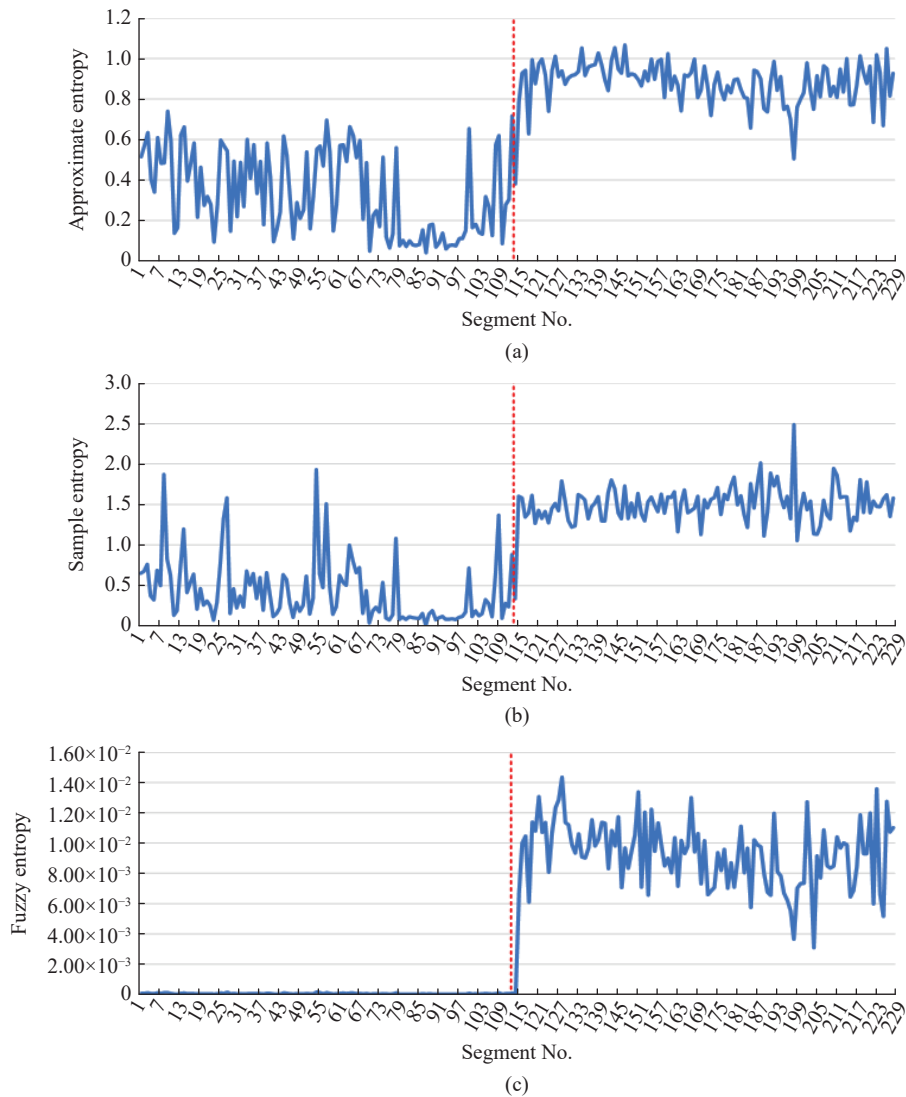
Based on it, we infer that people who get sick with Cyber-Syndrome are with higher entropic states. They are confused with symptoms in different CPST spaces, such as tiredness, fatigue, and pains in the physical space and depression as well as anxiety in the thinking space.

To prove our inference, an experiment is designed to measure the change of skin conductance of the right wrist before and after fatigue during long-term use of mobile phones. The subjects sit in a quiet environment with appropriate temperature and humidity. Before the experiment, they are asked to fill in the informed consent form and make sure that they have understood all the introductions. The experiment device is MP160 EDA100C manufactured by Biopac Systems Inc., with two electrodes and a sampling rate of 2000 Hz. Before and after the long-term use of mobile phones, the subjects need to fill in the Borg questionnaire to judge whether they are in a fatigue state or not. Finally, we divide the collected data in each state into 114 segments, each containing 100 samples.

As for the entropy analysis, we adopt the common nonlinear indicators of approximate entropy, sample entropy, and fuzzy entropy to analyze the characteristics of the skin conductance differences in the normal and fatigue state. The results are shown in Fig. 6.

The first 114 segments are data collected in the normal state before the long-term use of mobile phones, and the last 114 segments are data collected in the fatigue state. It can be observed that the 3 types of entropy in the fatigue state are all higher than those in the normal state. It proves that humans with discomforts are easily to get higher entropic states.

In order to recover from Cyber-Syndrome and keep a healthy state, people need to take action to reduce entropy in the body and achieve a balance. As Prigogine<sup>[39]</sup> mentioned in his Nobel lecture, an entropy formulation was proposed in the second law of



**Fig. 6 Entropy analysis of skin conductance between the normal state and fatigue state.**

thermodynamic. It is calculated by the entropy production inside and the entropy exchanged externally:

$$dS = d_iS + d_eS \tag{1}$$

where  $dS$  is the change of the entropy.  $d_iS$  refers to the internal entropy production, while the  $d_eS$  represents the entropy exchange with the outside. For humans, the internal entropy production mainly represents what takes place inside the body, and the external one refers to what takes place between the human body and the CPST space outside. Hence the total entropy production of the human body could be expressed as follows:

$$dS = d_iS + \sum_{x \in \{c,p,s,t\}} d_eS_x \tag{2}$$

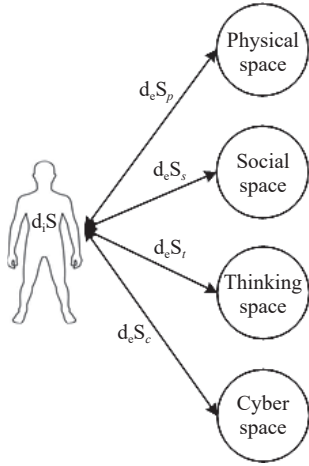
The equation refers to the entropy exchange with the cyber, physical, social, and thinking spaces, respectively.  $c$  refers to cyberspace,  $p$  refers to physical space,  $s$  refers to social space, and  $t$  refers to thinking space.

According to the second law of thermodynamics, the  $d_iS$  remains positive since any thermodynamic system would develop towards higher entropic states. The  $\sum_{x \in \{c,p,s,t\}} d_eS_x$  remains negative, since humans need to absorb negative entropy from the outside.

$$d_iS \geq 0 \tag{3}$$

$$\sum_{x \in \{c,p,s,t\}} d_eS_x \leq 0 \tag{4}$$

Figure 7 depicts the entropy production inside the human body and the entropy exchange with the



**Fig. 7 Entropy exchange of the human body between the inside and the outside.**

outside. In order to express it more conveniently, we use  $p(x, m)$ ,  $s(x, m)$ ,  $t(x, m)$ , and  $c(x, m)$  as the entropy exchanges over a period of time  $m$  in physical, social, thinking, and cyber spaces to replace  $d_e S_p$ ,  $d_e S_s$ ,  $d_e S_t$ , and  $d_e S_c$ , respectively, in the following description.

To the best of our knowledge, people with Cyber-Syndrome may present unhealthy states from the body inside, hence the value of  $d_i S$  keeps going up. This has been proved according to the experimental analysis in Fig. 6. Therefore, in order to keep the balance of healthy states, people with Cyber-Syndrome need to take action to slow down the increase of total entropy and try to keep healthy.

However, there are few behaviors affecting a single space independently. For example, people who eat a lot of protein could reduce the entropy in the physical space, meantime it also produces energy to take part in activities in social space. In other words, the behaviors of humans do not simply affect the entropy in a single space, but rather produce impacts on the CPST space as a whole. Given a certain human behavior  $x_i$ , where  $i \in \{1, 2, 3, \dots, n\}$ , there would be corresponding entropy influences of  $p_i(x_i, m)$ ,  $s_i(x_i, m)$ ,  $t_i(x_i, m)$ , and  $c_i(x_i, m)$  in respective CPST space. To note, the  $p_i(x_i, m)$ ,  $s_i(x_i, m)$ ,  $t_i(x_i, m)$ , and  $c_i(x_i, m)$  here are related to the behavior  $x_i$  and accumulated over a period of time  $m$ . Hence, the total entropy production of humans could be expressed as follows:

$$dS = d_i S + \sum_{i \in \{1, 2, 3, \dots, n\}} \int_{m_1}^{m_2} (p_i(x_i, m) + s_i(x_i, m) + t_i(x_i, m) + c_i(x_i, m)) dm \quad (5)$$

If someone gets sick with Cyber-Syndrome, the

value of  $d_i S$  would tend to increase with higher randomness and disorders. Therefore, the aim of controlling Cyber-Syndrome is to reduce the value of  $d_e S$ , in other words, to find the most useful actions that minimize the value of entropy change with the outside:

$$Z = \min \sum_{i \in \{1, 2, 3, \dots, n\}} \int_{m_1}^{m_2} (p_i(x_i, m) + s_i(x_i, m) + t_i(x_i, m) + c_i(x_i, m)) dm \quad (6)$$

where  $Z$  refers to the objective function, and there are internal relationships between different spaces. For example, the entropy changes in physical space may have influences on that in social, thinking, and cyber spaces. We define 4 constants  $\alpha$ ,  $\beta$ ,  $\gamma$ , and  $\epsilon$  as the impact factors of respective spaces. The hidden influence between different spaces could be expressed as Eq. (7).

$$\begin{aligned} p'_i(x_i, m) &= p_i(x_i, m) + \beta \times s_i(p_i(x_i, m), m) + \\ &\quad \gamma \times t_i(p_i(x_i, m), m) + \epsilon \times c_i(p_i(x_i, m), m), \\ s'_i(x_i, m) &= s_i(x_i, m) + \alpha \times p_i(s_i(x_i, m), m) + \\ &\quad \gamma \times t_i(s_i(x_i, m), m) + \epsilon \times c_i(s_i(x_i, m), m), \\ t'_i(x_i, m) &= t_i(x_i, m) + \alpha \times p_i(t_i(x_i, m), m) + \\ &\quad \beta \times s_i(t_i(x_i, m), m) + \epsilon \times c_i(t_i(x_i, m), m), \\ c'_i(x_i, m) &= c_i(x_i, m) + \alpha \times p_i(c_i(x_i, m), m) + \\ &\quad \beta \times s_i(c_i(x_i, m), m) + \gamma \times t_i(c_i(x_i, m), m) \end{aligned} \quad (7)$$

where  $\alpha + \beta + \gamma + \epsilon = 1$ .

In addition, the entropy in each space is not infinitely high or low, and it needs to be considered in light of the actual limitations. For example, people cannot participate in the intensive physical exercise 24 h a day for entropy reduction. There should exist a threshold  $\theta$  of entropy change in respective space, taking the real limits into consideration:

$$|p'_i(x_i, m)|, |t'_i(x_i, m)|, |c'_i(x_i, m)|, |s'_i(x_i, m)| < \theta \quad (8)$$

The control mechanism for Cyber-Syndrome is to reduce the generation of total entropy to achieve a balanced state. According to Eq. (6), we need to find the most influential actions that could reduce the entropy to the utmost. Usually, the principle is to absorb lower entropy from the outside and release higher entropy to it. In Table 3, we list some typical methods in respective spaces to control Cyber-Syndrome, which may provide guidance in practical applications.

## 6 Conclusion and Future Work

Cyber-Syndrome is a newly emerging disease mainly

**Table 3 Potential methods of controlling Cyber-Syndrome in CPST space.**

Space	Potential method
Physical space	Keep adequate sleep and rest; keep adequate nutrition; stop eating junk food; sunbathe; take exercise; speed up metabolism; keep living environment clean and bright; read more books and absorb useful information; take medicine as prescribed by doctors; etc.
Social space	Take part in various social activities; establish healthy and harmonious relationships with surroundings; abandon confused personal relationships; etc.
Thinking space	Absorb advanced ideas and viewpoints; get rid of outdated and backward concepts; keep good moods; seek and pursue the peace of mind; ask others for help; etc.
Cyberspace	Specify the time spent in Cyberspace to avoid time fragmentation; learn to identify and filter information online effectively; take the advantages of the Internet and avoid any harmful information or temptation; etc.

stemming from excessive interactions with Cyberspace and has close relationships with the PST space. In this paper, we provide a comprehensive definition of Cyber-Syndrome based on the theories of CPST space, and following that, we establish an overall understanding ranging from its etiology and formation, symptoms, and manifestations, to an entropy-based recovery mechanism.

So far, the research on Cyber-Syndrome is still in its infancy. Much of the existing work remains in the introduction of the concept, with little in-depth research on disease prevention and early detection. The work gives a comprehensive introduction to Cyber-Syndrome ranging from definition, etiology, symptoms, and control mechanism, and has opened a new research direction. In the future, we aim to find more ways of early detection of Cyber-Syndrome, depending on various social media data or physiological signals. More in-depth explorations of Cyber-Syndrome are needed in the future.

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**Liming Chen** received the BS and MS degrees from Beijing Institute of Technology, Beijing, China in 1985 and 1988, respectively, and the PhD degree in artificial intelligence from DeMontfort University, Leicester, UK in 2002. He is currently a professor of data analytics and a research director at Faculty of

Computing, and leads Cognitive Analytics Research Lab at Jordanstown Campus in Ulster University, UK. His research interests include pattern recognition, intelligent systems, smart environment, and assisted living.



**Feifei Shi** received the BS degree from China University of Petroleum in 2016 and the MS degree from University of Science and Technology Beijing in 2019. She is currently pursuing the PhD degree at School of Computer and Communication Engineering, University of Science and Technology Beijing, China. Her current

research interests include Internet of Things and artificial intelligence.



**Huansheng Ning** received the BS degree from Anhui University, China in 1996 and the PhD degree from Beihang University, China in 2001. He is currently a professor and vice dean at School of Computer and Communication Engineering, University of Science and Technology Beijing, China and the founder and principal at Cybermatics and Cyberspace International Science and Technology Cooperation Base. He has authored 6 books and over 180 papers in journals and at international conferences/workshops. He has been the associate editor of *IEEE Systems Journal* and the associate editor (2014–2018), area editor (2020–), and the steering committee member of *IEEE Internet of Things Journal* (2018–). He is the host of the 2013 IEEE Cybermatics Congress and 2015 IEEE Smart World Congress. His current research interests include Internet of Things, cyber physical social systems, and cyberspace data and intelligence. In 2018, he was elected as an IET fellow.



**Sahraoui Dhelim** received the MS degree in networking and distributed systems from University of Laghouat, Algeria in 2014 and the PhD degree in computer science and technology from University of Science and Technology Beijing, China in 2020. He was a visiting researcher at Ulster University, UK during 2020–2021. He is now a senior postdoctoral researcher at University College Dublin, Ireland. He serves as a guest editor in several reputable journals, including *Electronics Journal* and *Applied Science Journal*. His research interests include social computing, smart agriculture, deep learning, recommendation systems, and intelligent transportation systems.