# Collecting and Analyzing Successful Experiences in Difficult Collision Avoidance

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**ABSTRACT**

A recently developed safety concept called Safety-II has gained attraction to be implemented in a variety of disciplines. Safety II aims to ensure safety through flexible response and shows promising potential applications for the maritime domain. When considering effective safety training methods for nautical students and inexperienced navigation officers, it is necessary to develop new training methods based on the concepts of Safety II. This method of implementation needs to refer to the successful maneuvering experience of ship navigators. However, attaining meaningful maneuvering experience is difficult because the experiences like near-miss cases or minor accidents are not always reported in detail. In this study, we have determined the importance of learning from successful maneuvering experiences in difficult collision avoidance situations. Keeping these points in mind, this study aims to collect and analyze successful experiences in difficult collision avoidance. This study was successful in logging many different cases of successful collision avoidance. Results suggest that there is a difference between senior and junior navigators, and precautions, special training, etc. may be required in the ordinary practice of seafarers who face high cognitive demands in actual collision avoidance situations. Results also indicate that these precautionary techniques may require more than textbooks and classrooms to successfully train seafarers. The analysis carried out in this study clearly indicates that constructing a Safety-II-based training method can enhance young navigator proficiency to adapt to safe ship-handling even in complex situations.

## 1. Introduction

Over the years, many efforts have been made in the shipping industry to reduce accidents. These efforts include responding to proposed automation improvements, ship design, regulations, and human capabilities. Regarding human factor, the International Maritime Organization (IMO) has introduced the International Safety Management (ISM) Code in the SOLAS Convention (International Maritime Organization (IMO), 2013) and the 2010 revision of the STCW Convention, which stipulates Bridge Resource Management (BRM) capability (International Maritime Organization (IMO), 2010). In addition, other rules and procedures to overcome human error have also been made in many forms, including in the shipping companies, which have enacted measures such as establishing safety management and guidance systems. These efforts have proven to be effective in improving safety in the shipping industry.

The recent development of safety research has realized a gap between "work-as-imagined", on which the rules and procedures primarily are based, and work-as-done, where the actual performance takes place. This implies the promotion of new terms called Safety-I and Safety-II in the way of thinking about safety (Erik Hollnagel, 2014). While traditional Safety-I looks at what goes wrong to eliminate or create a barrier for failure to occur, Safety-II, on the other hand, is said to ensure safety through flexible response (Komatsubara, 2014). The Safety-II perspective is strongly related to resilience engineering (E. Hollnagel, Woods, & Leveson, 2006). This paradigm proposed an idea for safety management that focuses on how to maintain normally functioning system work in expected and unexpected situations. A system is said to be resilient by possessing four abilities; the ability to respond, the ability to monitor, the ability to learn, and the ability to anticipate (E. Hollnagel, Pariès, Woods, & Wreathall, 2011).

Along with this initiative, the functional resonance analysis method (FRAM) has been introduced as a new tool for assessing safety (Erik Hollnagel, 2012; Erik Hollnagel & Goteman, 2004). Summarizing all available published research in English about FRAM, 17 documents have been recorded using FRAM for safety analysis in the maritime domain. Most of them are used for re-analysis of maritime accidents. Those studies conclude that FRAM analysis could provide a deeper understanding of how functional resonance may have arisen, identifying the system's weaknesses, and suggesting proactive countermeasures for better operation (Patriarca et al., 2020). Although further research is needed, it has been pointed out that the concept of resilience engineering is promising in the maritime domain (Schröder-Hinrichs, Praetorius, Graziano, Kataria, & Baldauf, 2016).

On the hand, maritime simulation practices are still poorly understood in contemporary research (Sellberg, 2017). Resilience engineering offers a novel perspective with the potential to update current MRM（maritime resource management） regimes and offer new knowledge on how adaptability, flexibility, and safety in operations can be promoted through team training (Praetorius, Hult, & Österman, 2020). Given this background, it is important to consider more effective safety training methods for nautical students and those with little experience as navigators, learning, and experience with basic traditional nautical techniques. In addition to BRM training, which is a non-technical skill that has been pointed out to be effective, it is considered a good idea to develop a new training method that incorporates the concept of Safety-II.

Given this background, it is necessary to consider a more effective safety training method for nautical students and those with little experience as navigators to learn and practice basic traditional nautical techniques (KUNIEDA, YABUKI, TAKEMOTO, & TAO, 2004). In addition to BRM training (Campaniço Cavaleiro, Gomes, & Lopes, 2020; Röttger & Krey, 2021), which is a non-technical skill that has been pointed out to be effective, it could be a good idea to develop a new training method that incorporates the concept of Safety-II. Recently, IMO has been discussing the topic "Ensure Quality of Onboard Training" (International Maritime Organization (IMO), 2020), and it is thought that it can contribute to the future training technique from the viewpoint of streamlining and balancing Onboard Training (OBT) and Training Ashore (TAS). Thus, it is preferable for students to face the same conditions as they might face in actual ship operations (Kobayashi, 2005) but still use the Ship Handling Simulator for ship maneuvering and BRM training. The International Association of Maritime Universities (IAMU) has progressed this call for new training techniques that also focus on technical and critical cognitive skills as a focal point with their Global Maritime Professional (GMP) initiative, which states that future seafarers will need to be equipped with "with all the relevant technical competencies relevant to their specific operational role in the industry and as required by international requirements with high level academic skills including logical and critical thinking" (IAMU, 2019).

One central point connected to this topic is the necessity of Ship Handling Simulators in navigation training. During a simulation, most aspects usually work so well that it is not as easy to simulate the causes of failure that Safety-I considers in an accident or serious incident. Considering the adoption of the Safety-II concept, it is necessary to refer to the successful maneuvering experience of the ship operator to be applied in simulation scenarios. This raises the essential question of whether a successful ship maneuvering experience can be collected. It is similar to the case of extracting a "Good Job" from the aviation safety information voluntary reporting system (VOICES) based on Safety-II (Osawa, Takagi, & Nakanishi, 2020). The reported "Good Job" performance may be close to the near-miss situation that has been regarded as a case of the failure side that was about to lead to an accident or disaster (Heinrich, 1931). In this study, we considered a successful maneuvering experience in difficult situations could be regarded as a successful case. The essence of success may be derived from the accrual of successful experiences over a long career. Hence, this study attempted to collect the successful maneuvering experience of ship operators in difficult situations and aimed to analyze the collected experiences and clarify their characteristics.

## 2. Method

The study conducted an interview/hearing survey of people with practical experience in maneuvering ships. The hearing was carried out with the cooperation of 24 active Japanese ocean-going captains and officers. The participants consist of six Captains, seven Chief Officers, two 2$^{nd}$ Officers, and nine 3$^{rd}$ Officers. Of these participants, 13 of them were seniors, and 11 were juniors. All of the participants have a attained status of a 3$^{rd}$-grade maritime officer (Navigation) or higher in Japan. This qualification is equivalent to the certification of officers in charge of a navigational watch on ships of 500 gross tonnage or more, and masters and chief mates on ships of 500 gross tonnage or more which is specified in STCW Convention Annex Chapter II.

The individual interviews were conducted for approximately 15 to 20 minutes per participant by a trained student assistant who belongs to the navigational course in a meeting room (face to face), or online. Participants were asked to talk about the difficult collision avoidance situation they experienced (excluding harbor maneuvering), how they handled it, and what some important/relevant points were to teach to juniors, with attributes such as rank. Participants freely explained various situations with illustrations or writing as appropriate. In addition, deeper information was also obtained through the direct interviews on relevant points where the participant's explanation was difficult to understand. The interviews were recorded, then converted to text, and analyzed carefully by three researchers with extensive ship-handling experience.

The data analysis has been done using the KJ method (KAWAKITA, 1970). This method has been applied for qualitative studies for many years to organize fragmented information and ideas efficiently. The data collected from participants are subjective and unstructured. In addition, the data strongly tends to have a large variance. In this case, The KJ method is considered suitable to characterize this subjective information objectively and crate priority among the generated critical factors. Furthermore, it was pointed out that it can be utilized universally in a wide range of qualitative studies for decision-making in review of the KJ method (Scupin, 1997).

## 3. Result

### 3.1. Example of hearing results

The interview is expressed narratively and converted from an audio file. The narration shown below is a direct expression of the participant's story and is written in *italic* form (The original file uses Japanese and is translated to English by the author). Figure 1 shows the illustration of the actual situation that happened in the narrative example presented in this chapter.

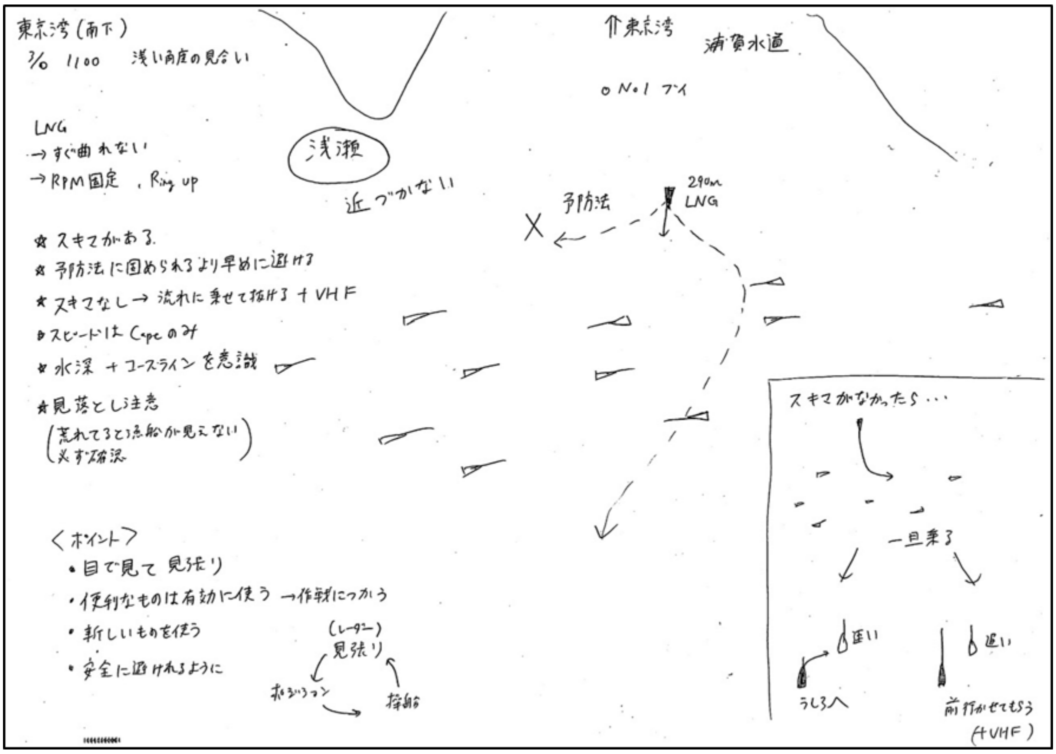


Figure 1. The illustration of the LNG carrier situation in the south of Tokyo Bay (This illustration figure is presented as written originally by the participant).

*"It occurred when I (the participant) was on a large LNG carrier, going south to Australia from Tokyo Bay. When she is about to leave Tokyo Bay, she must pass other ships with small course angles that were entering Tokyo Bay. This area was also congested. If she changed course to starboard according to CORLEG, she had to continue to avoid all ships by taking rudder to starboard, and then she could not go south. However, you can always find space, even in congested waters. So, at first, finding space between ships, taking action such as taking rudder to the port early before the encounter situation is a good way rather than nothing to do until the risk of collision occurs. Especially if you cannot find space such as many crossing coasters, once you make her course to the same way with coasters before the risk of collision occurs, then you can get their help through VHF communications. I think it is better to be a little careful. To keep a sharp lookout, to observe and consider the situation, then you take a rudder. You can always avoid a collision in this way. Everyone would like to know how not to fail, but there is no general. I am afraid to fail to detect. When the sea is rough, sometimes a small echo flickers appear on the RADAR screen. It looks different than a wave. In such cases, check the bearing of echo, and confirm it by using binoculars always. If you cannot find anything, order your quartermaster to confirm whether there is a ship."*

As mentioned in the previous chapter, participants are allowed to express their experience freely during the interview. Besides, deeper understanding of participant's story was also gathered by asking direct question while the interview takes place. Some important and relevant points have been underlined on the participant stories above. Thus, the richness and critical ideas expressed by participants were well presented in a comprehensive narrative. The analysis was done by underlying some important sentences such as how the participant handles the situation, as well as important and relevant points related to the idea of what can be difficult for the junior navigators.

### 3.2. Attribute of narrative

From 24 participants were interviewed in this study, some of them gave stories of several experiences.

Therefore, we managed data from a total of 36 cases of successful ship collision avoidance. In addition, the reported events did not only occur at their current rank. Many of the events occurred a long time ago, when senior (Captain and Chief officer) were junior navigators (2nd Officer or 3rd Officer). Table 1 contains information of the number of events given by participants and their rank when they experience the situation.

Table 1. Number of successful experience and participant's rank at the time of the event.

| Participants rank | N | Rank in the reported case | N |
|---|---|---|---|
| Captain | 13 | Captain | 5 |
| | | Chief Officer | 1 |
| | | 2nd Officer | 2 |
| | | 3rd Officer | 4 |
| | | - unknown - | 1 |
| Chief Officer | 11 | 2nd Officer | 5 |
| | | 3rd Officer | 6 |
| 2nd Officer | 2 | 2nd Officer | 2 |
| 3rd Officer | 10 | 3rd Officer | 10 |

Of the 36 cases collected from interview, Captains and Chief Officers (senior) reported 24 cases, and 2nd Officers and 3rd Officers reported (junior) 12 cases. Considering that there were 13 seniors and 11 juniors, the number of reports of seniors is about twice that of juniors. In addition, of the 24 cases reported by seniors, 17 of them occurred when the participating captains and chief officers were second or third officers.

Table 2. Type of ship maneuvered by participants when the reported event takes place.

| Own ship type | N |
|---|---|
| Container ship | 9 |
| LNG carrier | 7 |
| PCC | 5 |
| VLCC | 4 |
| Bulker | 4 |
| LPG carrier | 2 |
| Cruise ship | 2 |
| Training ship | 1 |
| Research vessel | 1 |
| - unknown- | 1 |

The size and type of the ship strongly affect officer performance in operating the ship. Therefore, to get a general overview of the complexity of maneuvering, we also characterized how the ship was operated by the participant at the time of the event. Table 2 contains the information regarding that matter. Although the ship size was not clearly stated, considering the shipping companies to which the participants belong, it can be inferred that most of them are large ships with a length of overall 200m.

Table 3. The location of the reported event

| Sea area | N |
|---|---|
| Singapore Straits | 8 |
| Malacca Straits | 7 |
| Coast of Japan | 7 |
| Mediterranean Sea | 2 |
| Coast of Vietnam | 2 |
| other | 8 |
| - unknown- | 2 |

Furthermore, the reported cases were also classified based on where the event occurred. Location can increase the complexity of the collision avoidance. Table 3 shows the sea areas with multiple answers in descending order. Singapore Straits has the largest number of reported cases, followed by Malacca Strait, and the Coast of Japan. This indicates that these situations mostly happen in congested waters. Another category are cases where only one reported case happened in that area; all of these occurred in coastal areas except for the South China Sea and the vicinity of Guam.

### 3.3. Result of the analysis

The analysis result was viewed in terms of rising complexity during the encounter, processes methods used by the officer to overcome the ship maneuvering situation.–Furthermore, all of the previously mentioned analytic points were summarized to extract key points that can be utilized for future curriculum and simulator design for younger seafarers to overcome difficult encounter situations in a more relevant way to the actual work.

Table 4. The situation increases the complexity of ship maneuvering.

| Situation | Captain and Chief officers (N) | 2nd and 3rd Officers (N) |
|---|---|---|
| Encounter with same way vessel in the congestion traffic (some cases accompany another factor such as fishing ship etc.) | 7 | 3 |
| Encounter with same way vessel | 1 | 2 |
| Crossing traffic (including crossing the TSS lane) | 5 | 3 |
| Maneuvering in the group of fishing boats (including the case of late detect other ships, and no RADAR detecting fishing boats) | 6 | 2 |
| Other | 5 | 3 |

Table 4 contains situations where difficulty was experienced by participants. Many of the reported difficult collision avoidance situations happened during multiple ship encounters. Congested waters are a factor in the causes behind the difficulties, but other scenarios include encounters with other vessels, crossing traffic, and maneuvering in a group of fishing boats. These situations require high understanding and proficiency to decide a suitable action to be able to overcome the difficult situations. Further extracted data providing insight into the action taken by participants to overcome the discussed difficulties are presented in Table 5.

Table 5. The action taken by participants to address the event.

| Methods for successful collision avoidance | Captain and Chief Officers (N) | 2nd and 3rd Officers (N) |
|---|---|---|
| Taking a large rudder angle | 6 | 1 |
| Using VHF Communication | 5 | 4 |
| Calling Captain | 4 | 0 |
| Making an adequate decision with a sharp lookout by his eyes and navigation aids | 4 | 2 |
| Adjusting her speed | 3 | 1 |
| Avoiding one by one | 2 | 1 |
| Blowing whistle | 2 | 0 |
| Nothing | 2 | 0 |
| Taking rudder to port | 1 | 3 |
| Others | 3 | 3 |

Nine points were extracted regarding the action taken by participants to successfully avoid collision. Specifically, effective communication such as the appropriate use of VHF, effective maneuvers such as steering with large angles, and adjusting speed were reported as methods for successful collision avoidance. In addition, three methods are reported only by senior navigators. In this case, Captains and Chief Officers reported that in a

Table 6. The important and relevant point to be taught to young officers.

| Important and relevant points | Captain and Chief Officers (N) | 2nd and 3rd Officers (N) |
|---|---|---|
| To consider other ships | 5 | 2 |
| Not hesitate to call the captain | 4 | 2 |
| Importance of sharp lookout | 4 | 2 |
| Importance of early collision avoidance | 4 | 0 |
| To have room to maneuver | 3 | 2 |
| To consider starboard to starboard passing | 3 | 4 |
| Appropriate use of VHF | 3 | 5 |
| To take large rudder without hesitation | 3 | 1 |
| To use the engine without hesitation | 3 | 1 |
| Effective use of navigational equipment | 2 | 2 |
| Other | 7 | 2 |

difficult situation, they would call the captain, blow a whistle, and nothing. But in this case “nothing" means to continue keeping a sharp lookout with doubt regarding the target ship.

The essence of learning from actual sailing experience has been presented in this study. In summary, ten important and relevant points, presented in Table 6, have been provided as factors that can be taught to the younger generation of seafarers. To consider other ships, not hesitating to call the captain, the essence of a sharp lookout, proper VHF communication, etc., were reported as points that junior seafarers should focus on learning. Furthermore, the appropriate use of VHF and starboard-to-starboard passing agreements are the most common methods used by 2nd and 3rd Officers to overcome a difficult ship encounter situation.

## 4. Discussion

This study was successful in logging many different cases of successful collision avoidance. Of the 24 cases reported by the Captain and Chief Officer, 17 cases occurred when the participants were 2nd and 3rd Officers. These experiences occurred long ago in the participants’ seafaring careers, suggesting that captains and chief officers have learned a lot from various experiences across their seafaring careers. Indeed, the 2nd and 3rd Officers have relatively less experience, but at least they have passed a couple of months on board training, showing that even young people have educational experiences.

The reported cases in this study show that many participants were boarding container ships, followed by LNG, PCC, VLCC, and bulk carriers. The size of the ships was not clearly stated, but considering the shipping companies to which the participants belong, it can be inferred that most of them were large ocean-going ships. There are many types of the ship included in the reports, most of which are merchant ships. Regarding the sea area of the reported cases, the Singapore Straits and Malacca Straits are the most reported areas where difficult situation occurred among the study participants. This is due to both the shipping routes of the companies involved in the study, and also because these areas are narrow and heavily congested. Many of these areas also have traffic systems, such as Traffic Separation Scheme (TSS). Another reported area where the difficulty was often experienced is the Coast of Japan. In addition, some participants also reported coastal areas in other countries, which indicates that officers in a ship-congested waters frequently face difficult situations.

Participant success in dealing with difficult situations was characterized by the encounter with other ships, crossing traffic, and maneuvering in the area with a vast number of fishing vessels. Results indicate that difficult situations are strongly affected by multiple factors such as ship encounters, shallow waters, currents, and so on. Although the actual situations are not simple, multiple ship encounters require officers to judge where and which ship is the safest to pass through. Furthermore, sufficient time is required to communicate and resolve the encounter with the other ship, during which time it can be hard to predict the other ship’s intention.

In addition, *Hokey et al.* (Hockey, Healey, Crawshaw, Wastell, & Sauer, 2003) conducted a study to measure the cognitive demands of a ship operator in simulated ship control. They found that in multiple ship encounter situations, the more ships involved, the higher the cognitive demands become. They also pointed out that the actions taken by ships that violate CORLEG will increase the cognitive demands further. The analysis of successful collision avoidance reported in this study also considers that more congested waters make encounter times longer and increase the number of other ships involved in the encounter situation. Furthermore, it is widely understood that actions that violate CORLEG occur when avoiding collisions. It is considered that successful collision avoidance in difficult situations reported in this study happened in a situation with continuous high cognitive demands.

When reviewing the collected data and subsequent analysis of how the ships involved in the survey events successfully avoided collisions in these various difficult situations, the captains and chief officers (senior navigators) suggested some important points, including taking a large rudder angle, using the VHF effectively, not hesitating to call the captain, keeping sharp lookouts, and appropriately-timed speed adjustments. These are the basics of safe ship navigation, but it is not hard to imagine that sometimes those actions are difficult to implement in actual situations, especially in complicated situations that may call for maneuvers that are not sufficiently practiced in training. For example, controlling the turning rate may become difficult by taking a large rudder angle. In addition, using VHF is one of the important techniques for avoiding collisions, although there is no specific description or regulations for VHF use in COLREG. Many junior navigators also reported using VHF in these situations. However, VHF radio communication is not always reliable (Sekine, 2020). It is important to use it carefully, at the right time, with adequate time to make the correct decisions and carry them out appropriately. Junior navigators may not have experienced calling for the captain yet in an emergency, and it will not be easy to build a relationship that allows them to be able to call the captain at any time without hesitation. According to some study participants, a sharp lookout is the most important proficiency for officers to have. However, even with a sharp lookout, it is extremely difficult for one person to always grasp everything, and maintaining an effective BRM is necessary. Regarding speed adjustment, junior navigators may not have much experience in adjusting ship speed. Hence, making the required speed adjustment will be difficult for them.

Many essential points can be extracted from learning about the successful experience of ship collision avoidance and then implemented in training materials for navigators. This study has extracted many highly suggestive items with details on how to implement them realistically. For example, the use of VHF is very useful in terms of confirming the intention of the other ship and communicating the intention of the own ship. In contrast, the issue of timing to use the VHF is important, and the reality is that not all ships, especially small ships, are equipped with VHF. Furthermore, a case was found during the interviews where the officers felt the danger of miscommunication; not being able to achieve mutual understanding due to the other ship's English ability.

By considering the situation of the other ship, passing starboard-to-starboard as an avoidance measure was also extracted. This encounter agreement is not mentioned in COLREG, but it is not prohibited, as long as no risk of collision exists. However, if officers want to perform passing starboard-to-starboard successfully, they have to consider some essential factors, such as a sharp lookout, early avoidance action, and maintaining a maneuvering margin. Although it is easy to summarize these points as separate factors, it is necessary to observe the actual implementation on the sea very carefully and make useful projections, which means that high cognitive demands will be necessary. This suggests that the implementation of specific avoidance actions determined by the encounter of ships described in COLREG is essential.

Learning from actual events of ship encounter situations has revealed that basic methods and practical methods were reported as ways to avoid collisions successfully. Basic points and practical points extracted from these reports are considered important for the training of junior navigators. The result of this study suggests that there is a difference between senior and junior navigators, and new measures need to be implemented for the ordinary training of seafarers with a focus on meeting the high cognitive demands required in avoidance situations. These training measures require "real-life" experience and/or extensive simulation training; classroom and textbooks are not enough to convey the skill and experience involved to successfully overcome difficult situations. Results from this study clearly indicate that constructing a Safety-II-based training method can enhance young navigator proficiency to adapt to safe ship-handling in complex situations. However, further research is required to construct new training methods based on the Safety-II concept. Because of Japanese captains and officers of ocean-going vessels often work on the land office as marine professionals, make their experience become shorter. It would be beneficial to update the MET apparatuses by utilizing new training methods based on the concept of Safety-II. It should also be noted that all new training systems that are developed based on the Safety-II concept can also contribute to operator training in regards to navigating with and around autonomous ships.

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